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Riggs Optical Company

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March 1st, 1934.

AN OPEN LETTER FROM ROY D. WETMORE

Recently I visited a number of refractionists in our territory for the purpose of getting a fresh view point on our organization and to determine for myself why so many men prefer Riggs Service. Although a number of good thoughts were given me, one customer summed up the whole story in about fifty words. Here it is:

"Roy, don't think for a minute that the only reason I give you business is because your work is good or your service prompt, I can get that in many places. There's a lot more to my loyalty than that. Of course, your products are good - but the additional services you render are what I like. Take for example your scientific department. They have helped me over obstacles lots of times. Your advertising department has solved my patient-getting problem and your financial department has taught me how to handle money matters in a sound matter. Altogether, Roy, Riggs gives me personal assistance, almost the same as you would expect from your own family - and believe me, that's what counts."

We have always thought that most everyone knew of these services to which every Riggs' customer is entitled, but perhaps we were wrong - many of you might not know that our interest in you doesn't stop with the sale of merchandise.

So that you may become thoroughly familiar with what Riggs has to offer, talk it over with your Riggs Representative and watch our advertising, it will contain information of value.

Sincerely yours,

Roy D. Wetmore

President

P.S. The idea of asking Riggs customers why they prefer Riggs has taught us a lot. Perhaps you can increase your practice by finding out why your present patients come to you. We'll wager that you'll discover enough "selling points" about yourself to attract many new patients.

AMERICAN JOURNAL OF OPTOMETRY

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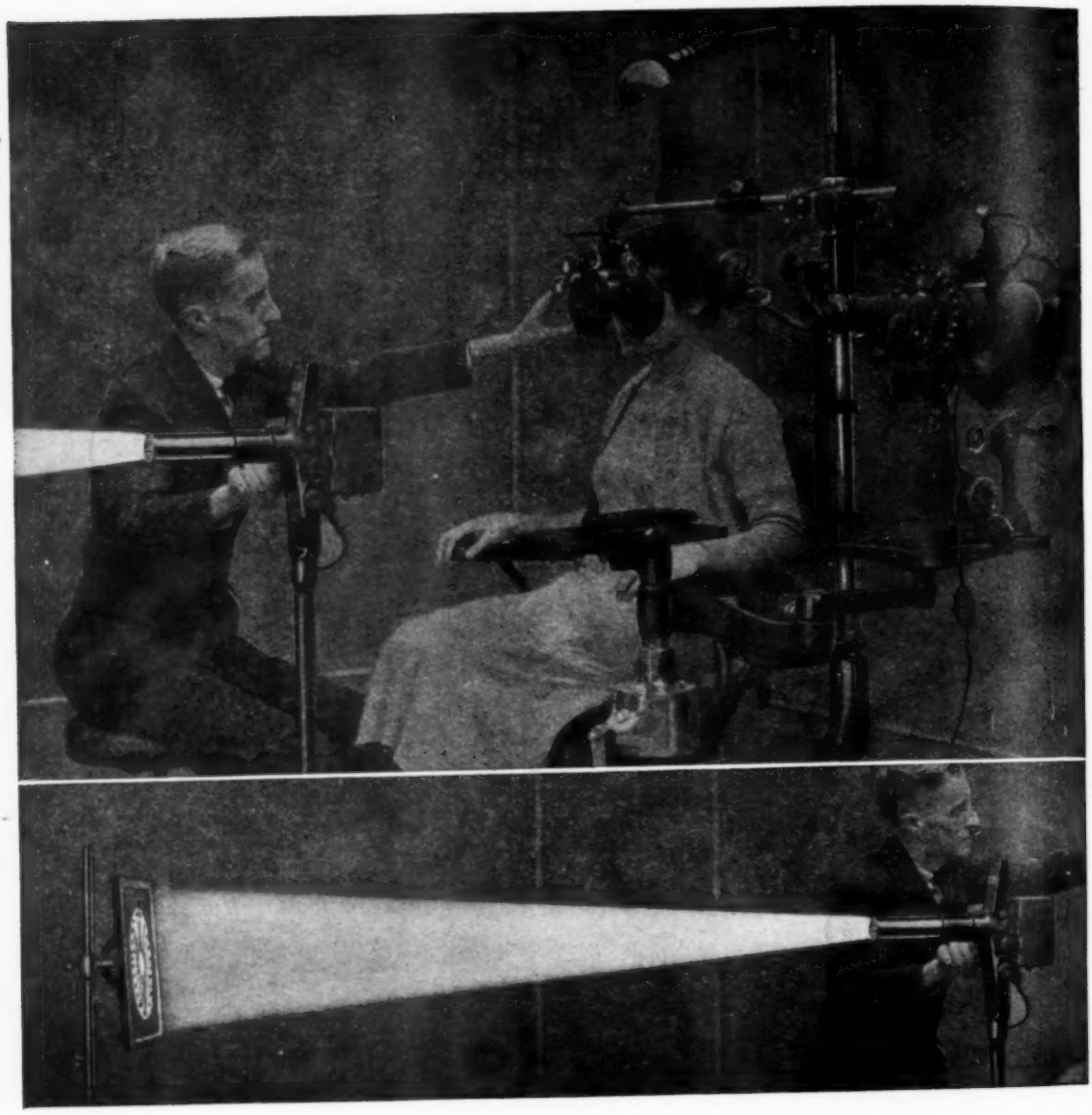

AMERICAN OPTICAL COMPANY 1833 1934 For Over a Century Manufacturers for the Optical Profession

A M E R I C A N

AMERICAN JOURNAL OF OPTOMETRY

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SOME PHYSICAL PROPERTIES AND BIOLOGICAL EFFECTS OF THE RADIATIONS OF THE ELECTRO-MAGNETIC SPECTRUM*

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I. PHYSICAL CHARACTERISTICS OF RADIANT ENERGY

Energy is being transferred constantly from one place to another. When this occurs something is moving and something else is being traversed; hence there must be a medium of transmission. Radiation is a form of energy and therefore may be produced from other forms of energy and may be converted, in turn, into other types. Heat energy is a convenient form for the production of radiation. For instance, the resistance offered by the filament of an incandescent lamp to the flow of electric current produces energy which is radiated as disturbances in the hypothecated ether. These regular disturbances, having varying wavelengths, are characterized as infra-red (heat), visible or ultra-violet light when they are intercepted and absorbed by a suitable body. Heat, for example, is not radiant energy but exists only when radiant energy is absorbed and ceases to be radiation. Radiations of proper wavelength, when received by the eye, cease to exist as radiant energy and become that which, in everyday parlance, is spoken of as light.

Radiant Energy—Its Oscillatory Character and Content of Energy.

Radiant energy is defined as a *periodic or rhythmic electromagnetic disturbance* traveling in the form of transverse waves with a velocity of approximately 186,000 miles (300,000 kilometers) a second. At first glance it is not evident that there is any connection between light, as we commonly designate it, and electricity or electric waves. Such a relation was predicted by Maxwell in 1864. In this theory mathematical proof was furnished that light waves are similar in character to electromagnetic frequencies which are given out by a body in which electric oscillations are occurring. A quarter of a century after Maxwell's epoch-

*Presented at the Eleventh Annual Meeting of the American Academy of Optometry, Chicago, Illinois, December 18-20, 1932.

making dissertation Hertz produced electric waves, thus giving experimental verification to the predictions of Maxwell as well as laying the foundation of wireless telegraphy and telephony. The periodic time of a complete oscillation (T) in a circuit containing capacity (C) and inductance (L) is

$$T = \pi \sqrt{LC}$$

This equation is of the same character as the equation for the periodic time of a complete vibration of a pendulum of length (l) oscillating under the force of gravitation (g), namely

$$T = 2 \pi \sqrt{l/g}$$

As the length of the pendulum is shortened the periodic time of a complete oscillation decreases or the frequency, or number of oscillations a second, increases. Following out the natural philosophy and laws underlying oscillations of pendulums and rhythmically oscillating surges in electrical circuits, we may accept the doctrine that oscillating molecules, atoms, and electrons are responsible for the portion of the gamut of radiant energy that extends from the infra-red rays to cosmic rays. From wireless waves to cosmic rays embraces about 60 octaves of the known electromagnetic spectrum.

All of the radiations of the electromagnetic spectrum carry *energy;* that is, the waves are the actual carriers of energy in transmission and hence, when absorbed, will produce heat, chemical action, ionization, or other physical changes, on the one hand, and, on the other hand, if absorbed by animal or plant tissues, there may result physiologic or pathologic effects. A considerable portion of absorbed radiant energy is converted ordinarily into heat. However, dependent on the wave-length and the energy content of the radiant energy, some of the energy may accelerate chemical action, enter into chemical reaction or be changed into electromagnetic energy of wave-length different than that of the energy absorbed. Radiations shorter than visible light, and known as ultra-violet rays are very active chemically, affect photographic films, ionize gases and other materials, produce photo-electric effects, cause phosphorescence and fluorescence, destroy bacteria, coagulate albumen and lens protein and cause increased absorption of calcium and phosphorus and their chemical combination in the formation of normal bone tissue.

In 1900 Planck published the famous *quantum theory* or atoms of energy constructed after the fashion of atoms of matter. Planck assumed the existence of vibrators of frequency v which could only possess energies represented by hv, 2 hv, 3 hv, and so forth. That is to say, the energy (E) of a vibrator is given by the expression

$$E = Nhv$$

in which *N* is 1, 2, 3. . . . and *"h"* is a number, known as Planck's constant, expressed in a unit called the erg-second and thereby stating that energy is dissectable and divisible into definite units or quanta. The

relative magnitudes of the quanta of energy are somewhat as follows:

TYPE OF RADIANT ENERGY	FREQUENCY (v)	RELATIVE ENERGY $E \propto v$
Red light	4×10^{14} cycles	1
Violet light	8×10^{14} "	2
Ultra-violet	3×10^{15} "	8
X-rays	3×10^{18} "	8,000
Gamma rays	3×10^{19} "	800,000

Beyond the Reds and the Blues

If spectra produced by carbon or metallic arcs and by incandescent vapors and gases are examined visually it appears that the wave-lengths emitted lie between 4,000 and 7,700 Angstrom units—the Angstrom unit being 10^{-8} cm. or 1/100,000,000 cm. These are, respectively, the violet and red limits of the visible spectrum and also the limits of the physical spectrum as known from the time of the discovery of the visible spectrum by Newton in 1665 until nearly a century and a half later. Herschel showed, in 1800, that there were radiations with wave-lengths longer than the eye could detect. These radiations are called *infra-red* rays and differ physically from visible light only in their wave-length. They are detected most readily by the heat generated when they are absorbed by thermocouples or by the blackened platinum strips of bolometers. Instruments for the measurement of their wave-lengths must be specially constructed. Glass does not transmit infra-red waves longer than 3 microns—a micron being a thousand of a millimeter. The best materials are rock salt and sylvite.

Soon after the discovery of infra-red rays, Ritter and Wollaston found that a spectrum might contain also wave-lengths shorter than any the eye could detect. These radiations were called ultra-violet rays. These rays are usually not present in sufficient quantity to allow use of the method of heat-detection, as in infra-red rays. They are, however, very efficient in promoting certain chemical reactions and are sometimes called actinic or chemical rays. This property is due to their short wave-lengths and hence high frequency. This frequency and accompanying content of energy are often high enough to expel electrons from atoms and thus inaugurate chemical processes or instigate chemical reactions. Physically, however, they differ from visible light only in shortness of wave-length and greater energy content.

Ordinary glass will transmit only ultra-violet rays having wave-lengths longer than about 3,300 Angstrom units. Hence instruments designed for investigating ultra-violet rays must be constructed of quarts (transparent to 1,900 Angstroms) or of fluorite (transparent to 1,200 Angstroms). Air absorbs ultra-violet radiations shorter than 1,800 Angstroms.

Ultra-violet rays with wave-lengths between 2,900 and 3,100 Angstroms have been found to promote health and to cure some dis-

eases, notably rickets. These rays are referred to frequently as "vital rays." They are present in sunlight and in electric arcs and sparks when not enclosed by glass. The mercury arc in quartz is a particularly rich source of these rays.

The Complete Electromagnetic Spectrum

The discovery of wave-lengths of light which were longer and shorter than the eye could detect led to many investigations which extended the spectral limits farther and farther beyond the visible red and blue respectively. In the course of these various investigations Hertz, as I have stated previously, discovered waves radiated by oscillating electrical circuits which had all the properties of light, such as interference, polarization and diffraction as well as having the same velocity as light in a vacuum. The wave-lengths of *Hertzian waves* may be measured by observing the nodes and loops of stationary waves produced when they travel along parallel wires (Lecher system) and are reflected. In the case of the longer waves used in radio, the wave-lengths may be determined by calculation from the values of the inductance (L) and capacity (C) of resonating circuits.

Not long after the discovery of Hertzian waves Roentgen, in 1895, found another type of radiation which was shown later to be similar to light but possessing a wave-length shorter than that of ultra-violet rays. The rays discovered by *Roentgen* are named after him or are referred to as *X-rays*. Their characteristic peculiarity is that they pass through many materials which are opaque to visible or ultra-violet rays. This is particularly true if the rays have a very short wave-lengths. Such rays are said to be "hard." The shorter the wave-length the "harder" the radiation becomes and the more penetrating it is. A study of the emission of Roentgen rays shows that there is a simple relation between the voltage (kilovolts) and wave-lengths (Angstrom units). Thus it is found that the shortest wave-length (λ min) emitted is given by the formula

$$\lambda \text{ min} = \frac{12.34}{V}$$

Roentgen rays are emitted whenever electrons with a high velocity strike a metallic target. In modern tubes the electrons are obtained by heating a filament to incandescence. The electrons are driven against the metallic target when a high voltage is applied between the filament and the target. The higher the voltage, and therefore the velocity, the shorter the wave-length and the greater the hardness of the rays. Wave-lengths of X-rays are measured by using a crystal as a diffraction grating mounted on a suitable spectrometer. The diffracted rays are not directly visible but can be made so by means of a fluorescent screen, photographic plates or ionization chambers. If D represents the distance between atomic planes of the crystal and A the angle between the planes and a line in the direction of some maximum of diffraction, the wave-length producing this maximum is given by the formula

$$m \lambda = 2 D \sin A$$

where m is an integer indicating the order (first, second and so on) of the spectrum. The value of D must be known before the former can be used to measure wave-lengths. In the case of a simple cubic crystal the value of D can be found from the values of its density and the weights of its atoms. Thus, for rock salt the value is D = 2.814 Angstrom units when the cube faces are used to reflect the X-rays.

Two more divisions of radiations must be added to the list of the electro-magnetic radiations extending in wave-length from electric waves to Roentgen rays. Rutherford, Wien and the Curies found that many radioactive substances radiate a very penetrating type of X-ray which has been called the *gamma ray*. Since alpha and beta rays consists of postively and negatively charged particles respectively, they are excluded from the list. The wave-lengths of gamma rays are so short that crystals, with their atomic arrangements, are too coarse to produce diffraction. Furthermore, the electrons liberated by these rays have a velocity so fast that it is impossible to apply an electric field sufficiently powerful to stop these electrons and thereby calculate the wave-lengths. But these high speed electrons may be deflected from their paths by means of a magnetic field and the radius of curvature of the path of deflection may be measured. From these data their velocity and wave-lengths may be calculated.

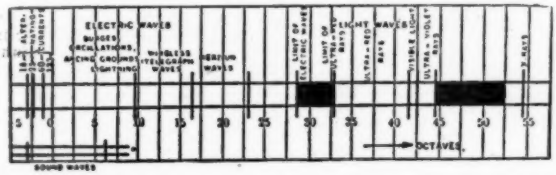

Fig. 1. The range of frequencies of radiation covers 60 octaves (After Steinmetz: *Radiation, Light and Illumination*, 1909). The two gaps, indicated by dark areas in the schema, have been closed since 1909.

Another kind of radiation having a wave-length still shorter than the gamma ray was discovered by Kohlhoester in 1914 and again by Millikan in 1919. These are called *cosmic rays* because they seem to come from interstellar space. They are spoken of as the "birth cries" of matter by Millikan and the "death wails" by Jeans. They have an enormous penetrating power, being able to pass through many feet of earth or water and a few feet of lead. From their high penetrating power and from the formula which has been found to correlate penetrating power with wave-length in the spectrum of X-rays and gamma rays it is estimated that the wave-lengths of cosmic rays are about as much shorter than X-rays as the wave-lengths of X-rays, in turn, are shorter than visible light.

For a number of years two unexplored gaps existed in the electro-magnetic spectrum: (1) between ultra-violet light and Roentgen rays

TABLE OF PHYSICAL PROPERTIES OF THE DIFFERENT

Division and Name	Radio and Hertzian Waves	Infra-red Rays	Visible Rays
Velocity			186,000 miles a second
Wave-length	Several kilometers to about 1,000,000 A. or 0.1 mm.	1,000,000 A. to 7,700 A.	7,700 A. to 4,000 A.
Wave-length measured by	Resonating circuits and waves on wires	Interferometers and spectrometers	Grating and prism spectrometers
Generation	Oscillatory discharges of condensers	Radiation from hot bodies	By incandescent substances and ionized gases
Detection	Coherers and thermocouples	Bolometers and thermocouples	Vision, photography, certain chemical reactions
Reflection	By sheets of metal	By polished metallic surfaces	By ordinary mirrors and polished surfaces
Refraction	By large prisms of pitch	By prisms of rock salt	By prisms of glass and transparent substances
Diffraction	With widely spaced wire gratings	With coarsely ruled gratings	With ruled gratings on glass or metal
Penetration	Penetrating, especially short electric waves	Slight penetration; rapidly absorbed by water	Slight penetration of body; of greater penetration than long infra-red
Discovers	Hertz (1889) Tesla (1893) Lodge (1888) Righi (1894) Nichols and Tear (1923)	Herschel (1800) Langley (1886) Rubens (1896) von Bayer (1912)	Newton (1665)

RADIATIONS OF THE ELECTROMAGNETIC SPECTRUM

Ultra-violet Rays	Roentgen Rays	Gamma Rays	Cosmic Rays
4,000 A. to 150 A.	150 A to 0.5 A	0.5 A to 0.005 A	0.0007 A to 0.0004 A
Grating and prism spectrometers and photo-electric effects	Crystal diffraction	Magnetc deflection of secondary beta rays	Penetrating power
By very hot bodies and ionized gases	By the sudden stoppage of rapidly moving electrons	By disintegration of atomic nuclei	By annihilation of matter and release as radiant energy
Photography, chemical effects, fluorescence, ionization photo-electric effects	Photography, chemical action, ionization	Phosphorescence, chemical action very vigorous, discharge of electroscopes	Discharge of electroscopes
By liquid and various substances, especially nickel, silicon and magnalium	No ordinary reflection	?	None known
By prisms of quartz or fluorite	No ordinary refraction	?	None known
With very finely ruled gratings	With crystals	?	None known
Very slight penetration, except quartz, fluorite, water and air	Penetrates all matter to a greater or less extent	More penetrating than X (Roentgen) rays	Extremely penetrating; through several inches to feet of lead
Ritter (1801) Cornu (1878) Schumann (1893) Lyman (1915) Millikan (1920)	Roentgen (1895) Holweck (1921)	Rutherford (1919)	Kohlhoerster (1914) Millikan (1919)

and (2) between the longest infra-red rays and the shortest Hertzian rays. These two gaps are indicated by the blackened regions in the gamut of electromagnetic radiations shown in the illustration (Fig. 1) taken from a book entitled *Radiation, Light and Illumination* by Steinmetz and published in 1909. The gap between the shortest electric wave and the longest infra-red ray was closed in 1923 by the work of Nichols and Tear. These investigators used extraordinarily delicate electrical oscillators and resonators as well as specially designed radiometers and interferometers. The region between the shortest ultra-violet ray and the longest X-ray was completed in a rather novel fashion. A beam of X-rays will eject electrons with a velocity equal to that required to produce them. The velocity may be measured by applying a retarding potential to a grid, through which electrons are streaming, until the potential is sufficiently high to stop them. The retarding potential necessary to stop the electrons is related to the wave-length by the expression

$$\lambda \text{ min} = \frac{12.34}{V}$$

In this manner the gap between X-rays and ultra-violet light was bridged. Since these long X-rays are absorbed readily by air, the experimental apparatus was enclosed in an evacuated chamber.

We have, therefore, a greatly enlarged spectrum—the electromagnetic spectrum—consisting, at one extremity, of the series of Hertzian or wireless waves sometimes having a wave-length as long as 30,000 meters, passing through several octaves of infra-red rays to the single octave of visible light, thence through the ultra-violet region to X or Roentgen rays, then the gamma rays given off by radium and finally the ultra-gamma or cosmic rays—to which Millikan, Compton and Piccard have given so much attention during the past year or two—with wave-lengths as short as 0.0004 Angstroms or 0.000,000,000,000,4 meter.

II. GENERAL CONSIDERATIONS REGARDING THE BIOLOGICAL EFFECTS OF RADIANT ENERGY

In one of the opening paragraphs of the monograph *Physiological Effects of Radiation* (Physiological Reviews, 8:1-91, January, 1928), Laurens wrote:

"Those interested in the biological and therapeutic action of ultra-violet, visible and infra-red radiations are often discouraged because of inconclusive or conflicting results, and above all because of an inability to more than hint at plausible reasons for the reactions obtained on normal and abnormal animals, organs or tissues. The biologist and clinician, however, should not feel discouraged, for there seem to be but few instances of photochemical effects where the physical process is understood. Furthermore, the lack of agreement between practical and therapeutic results on the one hand and scientific or experimental on the other is due to the fact that the experimental observations have

been made for the most part on healthy men and animals, while the practical or therapeutic results have been obtained on diseased persons. The sick organism is a much more delicate mechanism than the well, diseased tissue being much more susceptible to radiation than normal, while the animal skin is an entirely different organ from the skin of man."

While but relatively little regarding photosynthetic processes is known, it is believed that they are the only means by which one can store up the energy from the sun's radiation (or radiations from artificial sources of radiant energy such as carbon arcs, quartz-mercury lamps and the like) in the form of useful work, and their products are the greatest objects of the struggle for existence. For as Nernst (*Theoretical Chemistry*, Ed. 5, London, p. 902: Macmillan and Co., 1923) expressed it in the closing paragraphs of his treatise on theoretical chemistry:

"The struggle for existence is therefore, as Boltzmann emphasized, not a struggle for fundamental material—the fundamental material for all organisms is present in excess in earth, air and water; it is not even a struggle for energy itself, for quantities of energy fill our environment in the inconvertible form of heat; it is a struggle for the *free energy available for work*, which the plant world stores up from the sunlight, as electrical energy is stored in an accumulator . . . There can be no doubt that a thorough explanation of the *transformation of radiant energy into chemical* would be a success of the highest importance and a further step towards the goal which theoretical chemistry even now makes possible, of placing side by side and in perfect equality with the doctrine of the *material* changes of nature, so long the chief interest of the scientist, a *doctrine of transformations of energy.*"

Photochemical Activation

As the result of the experimental work carried out with my colleagues, I have formulated the theory that vitamins are not necessarily new substances but may simply be certain atoms and molecules which have been photoelectrically or photochemically activated. According to modern electronic theories, this activation of inert atoms and molescules may be conceived of as being due to the fact that energy contained within certain wave-lengths of radiant energy ionizes (that is, either causes an addition or a subtraction of an electron or changes the energy level of an electron according to the Bohr theory) atoms in complex chemical substances and thereby endows them with new activities, properties and powers. After all is said and done, an ionized atom or molecule of calcium, phosphorus or what not is not the same entity as a nonionized molecule or atom, for the ionized molecule or atom has, figuratively speaking, its arms wide open to grab, whereas the nonionized substance has its arms folded and is, so to speak, at rest chemically.

The vitamins, such as vitamin D (which is manufactured by the invisible rays of sunlight, carbon arcs or quartz-mercury lamps or is

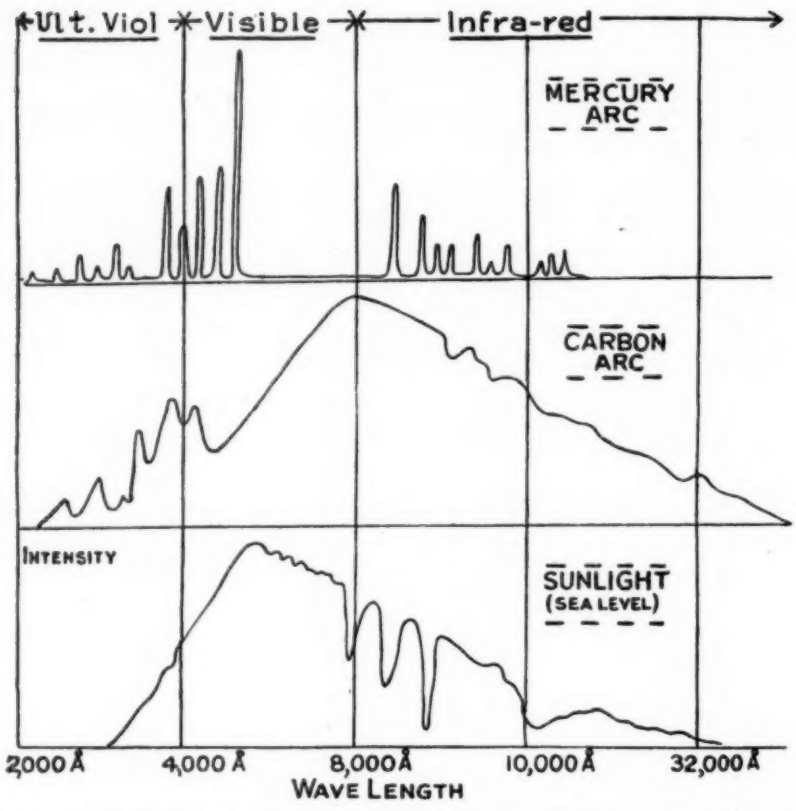

Fig. 2. Distribution of energy in the spectra of the mercury arc, carbon arc and sunlight (After Griffith and Taylor, *Radiology*, 1928).

found in fresh, good quality cod liver and other oil) are doers, workers and energizers. They may simply be active forms of complex molecules of the mother substances, or, again, they may be catalyzers, *i. e.*, substances that act as go-betweens, or handers-on, and which take the unavailable and make it available in some mysterious manner. Perhaps they are substances which act like the trigger in the gun, which, when it is pulled, sets free the pent-up and previously unavailable energy of the gunpowder.

The Physical Problem

Investigators are now in possession of a great deal of general knowledge pertaining to the effects of radiant energy but are somewhat lacking in specific details, such as spectral limits, spectral distribution of energy and the spectral character of the radiant energy employed, such as are shown in the curves of Figure 2. The absence of data pertaining to the source employed and the nature and amount of

radiation, are the cause of the contradictory nature of many of the therapeutic and experimental results that have been published. For instance, the distribution of energy in the various lines of the quartz-mercury arc lamp can be modified greatly, as shown in Figure 3, by the input of energy (dependent on voltage and current), whether water-cooled or air-cooled, and on the presence or absence of selective filters. And, again, a Simon-pure source of ultra-violet (in which all visible and infra-red portions of the spectrum are excluded) has never been

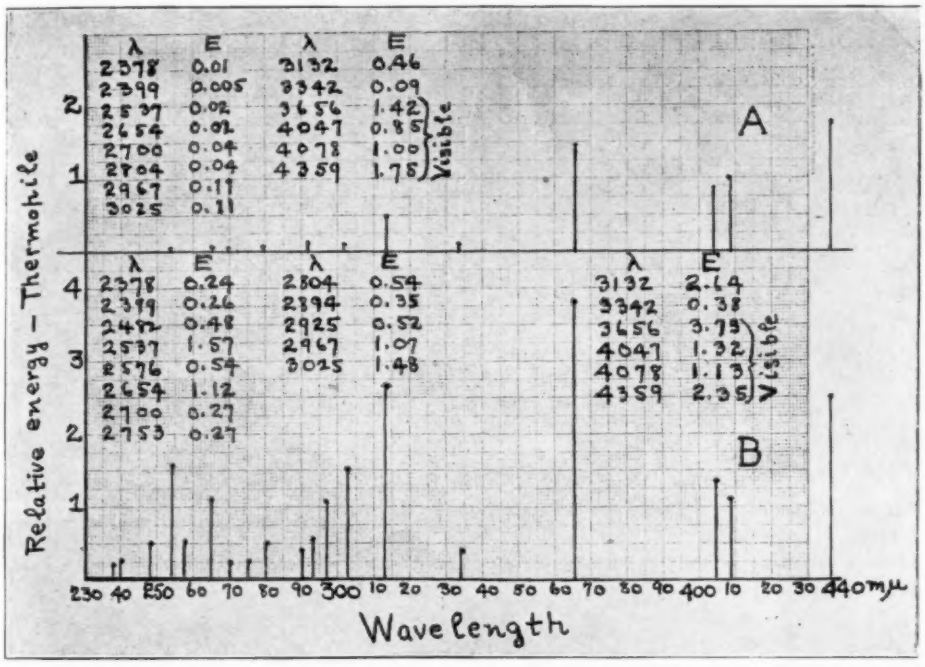

Fig. 3. The energy emitted by sources of ultra-violet light is affected by the input of energy. Relative energies of radiations from an air-cooled mercury arc: (A) Operated at 70 volts, (B) operated at 90 volts. (After Sheard and Higgins: *Journal of Experimental Zoology*, 1931.)

used, to the best of my knowledge, in therapeutic work. Dosage, therefore, and therapeutic results must be dependent on the quality and quantity of the radiant energy absorbed by the tissue. Since it is very difficult to determine the percentage of incident radiant energy absorbed by any tissue, one must be satisfied at the present time with the determinations of the quality and quantity of radiation incident at the site of irradiation and the correlation of such measurements with biologic and clinical observations. It is easily conceivable that normalcy of functions of a given tissue might be stimulated by a certain quantity of radiation of a given spectral character, but that dysfunction or vital

impairment might occur under excessive or lethal dosage, or, again, no demonstrable effects might be obtained because of insufficiency of radiation.

The Biologic Problem

The physical problems regarding quantity and quality of radiation can be solved fairly satisfactorily. With Roentgen rays, quartz and visible spectroscopes and other physical apparatus, data can be obtained regarding the quality of the radiation. With spectrophotometers, monochromators and thermopiles, and ionization chambers, one can measure the quantity of the radiation in any specified spectral line or region.

The biologic problem is much more difficult. These difficulties, in brief, are as follows:

Supplies and Demand, Excesses and Deficits—The general philosophy of the law of supply and demand is just as applicable to the animal or plant organism as to the world of finance. The strength or weakness of a business institution can be ascertained fairly readily by obtaining an accurate record of such assets and liabilities. It is difficult to obtain an accurate record of such assets and liabilities in the case of animal and plant organisms, for, as has been pointed out, the sick organism has a mechanism differing from the one that is well. It seems to me that those who practice in anywise on the human body frequently fail to appreciate the fact that certain symptoms, such as those included under the term discomfort, as well as untoward effects produced by certain causes, such as focal infections, are somewhat in proportion to the presence or absence of a state of well-being. In brief, when functions are strong and possess ample reserves, they are capable of meeting demands or of offsetting deficits, which would be impossible when these functions are weak. The biologic problem is, therefore, the determination of the quality and quantity of the reserves and of the deficits.

Environmental and Hereditary Factors—In an article by A. G. Ingalls (*Ultra-violet Transmitting Glass: Has It Made Good?*, Scientific American, April, 1929, pp. 338-343) I was quoted as saying: "Mr. Heinz with his fifty-seven varieties of pickles has nothing on the biologist, biophysicist and biochemist as they endeavor to draw conclusions relative to the effects produced by such an agent as ultra-violet light." No, indeed, Mr. Heinz has not made a start, for we have fifty-seven (or more) varieties of ancestors, environment, habits, diets, mental outlooks, nervous constitutions, etc. There are susceptibilities and immunity or developed resistance, tendencies to weakness or elements of strength. Therefore, to a very large extent, each patient as he presents himself to his consultant is a distinct problem and a law unto himself. The biologic spread is a wide one. If a certain type of treatment can be shown to be efficacious in a reasonable percentage of cases, one may well believe that such knowledge is of value and will form

the basis for further investigations covering the types which respond favorably or unfavorably.

Conclusions Drawn from Experimentation on Animals and Plants—The skin of an animal is, in many respects, different from the skin of a man. Again, it is a long, long way from an ameba or paramecium to a man. Investigators get clews and first-hand information from experiments on animals. Although one cannot, for example, draw absolute conclusions from animal experimentation relative to the effects of radiant energy (as to both quality and quantity) on the human subject, in calcium and phosphorus metabolism, the growth and development of the parathyroid glands, etc., under controlled conditions, one may find out much regarding the factors involved in the prevention of rickets and the development of normal calcification and normal parathyroid glands.

Theories of Action or Effects of Ultra-violet Irradiation

Some of the theories regarding the effects of ultra-violet irradiation may be summarized thus:

1. Radiant energy acts only in proportion to the total energy absorbed (Grotthus).

2. The fats and lipoids of the skin become photo-active after irradiation (Harthausen, Hess and Weinstock, Steenbock and Hart).

3. Ultra-violet radiation coagulates albumin, destroying superficial cells with liberation of ferments and their subsequent absorption (Pincussen).

4. Ultra-violet radiation increases the hemobactericidal properties (Colebrook, Leonard Hill, Eidinow and others).

5. Fluorescent substances in the skin, such as quiniodin, when irradiated become toxic to micro-organisms and this toxic substance can stimulate nerve endings (Dixon).

6. Ultra-violet light increases the absorption of calcium and phosphorus of, or in, the intestines, probably owing to the effects on metabolism caused by the absorption of irradiated cholesterol from the skin (Webster, Hill, Robinson and others).

7. Ultra-violet radiation induces changes in the electrical condition of protein, altering the hydrogen-ion concentration; that is, a form of protein shock (Duke-Elder, and others).

8. On being oscillated, cells convert the oscillations into nerve stimuli. From this stimulation, erythema is indirectly produced.

9. Hypertrophy of parathyroid glands occurs after exposure to ultra-violet rays (Grant and Gates). Normality of development and function of the parathyroid glands are dependent on the presence of both ultra-violet and visible rays; whereas, hyperplasia and hypertrophy of the glands occur under either ultra-violet rays or the longer and the shorter wave-length portions of sunlight when chickens are fed a ration poor in antirachitic vitamin (Sheard and Higgins).

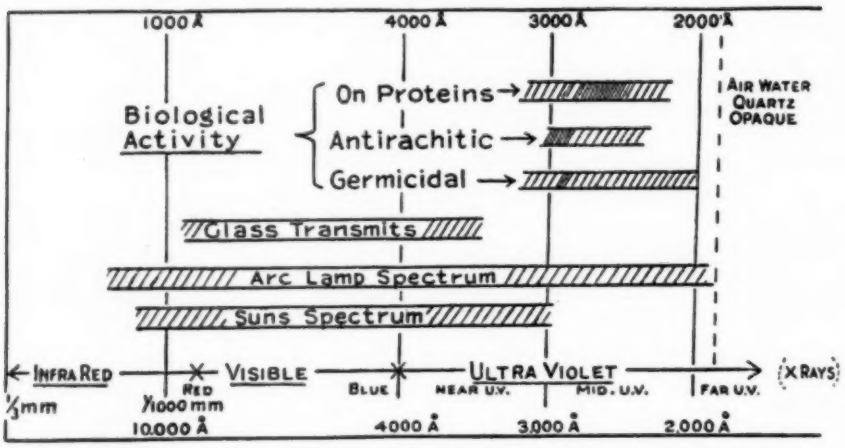

Fig. 4. Diagrams showing the biological activity of ultra-violet radiations and the spectral ranges of the sun and arc lamps (After Griffith and Taylor, *Radiology*, 1928).

10. The nuclei of cells are particularly absorptive of ultra-violet energy. The subsequent toxin derived from the splitting up of the chromatin brings about an increased blood supply (L. Hill).

11. Ultra-violet irradiation temporarily paralyzes the sympathetic nerve endings in the skin, which causes tonic depression of the whole sympathetic system. The result is inability of the suprarenal glands to convert tyrosin into epinephrin. Instead, this tyrosin is converted into melanin in the skin (Hertel, Rothman).

12. Effects are due to photoelectric and photochemical actions, and production of ions and of activated compounds. Quantum levels of electrons may be changed under ultra-violet irradiation and the resultant reradiation of energy permits this process of activation to continue for extensive periods (Baly, Bovie, Sheard).

13. Ultra-violet irradiation causes activation of ergosterol. This substance has no calcifying action, but when exposed to ultra-violet light of certain strength and for certain periods, it has a calcifying power which is at least a hundred thousand times as great as that of ordinary cod liver oil (Hess, Windhaus, Barger, Rosenheim and Webster).

14. Ultra-violet rays act by producing inflammatory reactions with the determination of more blood, lymph and lymphocytes to the part, and by altering the immunizing power of the body (L. Hill).

Bottled and Unbottled Radiant Energy

At any rate, life is a dynamic relationship between structure and environment. The cell is the unit of life and is essentially a transformer of energy. In fact, the living cell may be regarded as a large electrified molecule surrounded by a shell of attendant positive or negative ions. Starting with the epoch-making suggestion of Planck

that radiation is emitted in discrete units proportional to the frequency, Einstein was led to formulate the idea of corpuscular quanta of radiation or photons in order to account for the photoelectric effect. Recent experiments by A. H. Compton, Davisson and Greiner, and Dempster, using Roentgen rays, negative electrons and positive ions, respectively, have seemed to establish this corpuscular theory. Yet it has been known for a long time that light has the characteristics of waves. So, today, one continues to think that radiant energy (electric waves, infrared, visible, ultra-violet, Roentgen and gamma rays) is propagated as electromagnetic waves, yet the energy of the light is concentrated in the particles associated with the waves. Hence, whenever light does anything, it does it as particles. The energy of the particles of the light waves, when absorbed, modifies the content and distribution of energy in the substance which absorbs it.

The human body is a myriad of cells: its covering, the skin, is everywhere studded with sensitive spots, or eyes, and each of these groups of receptors is tuned to radiations of definite range of wavelength. The influence of this reception of energy is conveyed internally to millions of cells situated in different tissues. This energy of radiation, largely, from the sun, the great light "created in the beginning," changes matter (which is, in the last analysis, nothing but condensed energy), alters it, evolves it and endows it with new properties.

Ultra-violet rays penetrate to the deeper epidermal cells but no farther. Therefore, ultra-violet light does not penetrate the organism deeply enough to reach the bones, for example, and hence cannot be thought of as the agent which acts directly on bone tissue or which affects the growth or differentiation of tissues. Its stimulating action must be transferred, therefore, in some manner, from the medium in which it is absorbed, the skin of the body, to the bones. In plants, for example, we find that illuminating one portion of a plant affects the differentiation and development of the parts not exposed to the light. Since plants have, as far as we know, no specialized nervous tissues and nerve systems to act as receptors of energy or as modifiers of such energy when absorbed, it may well be concluded that photochemical products are formed in both plants and animals and that these photoproducts, or "formative materials" as someone has called them, bring about the differentiation. And, as Bovie has suggested, it is not impossible that the action of light on the blood is similar to that of light on a photographic plate. On exposure of a plate to light, a latent image is formed which is due to photochemical reactions and which ultimately is developed and fixed with suitable chemicals to give the final image, or "negative" as it is spoken of ordinarily. Light acting on the blood stream produces photochemical reactions which may be conceived of as latent images in the blood, which, in turn, may be developed by the chemical interactions which occur in connection with the metabolic changes having to do with the differentiation of tissue.

TABLE OF BIOLOGICAL PROPERTIES OF THE DIFFERENT

Division and Name	Radio and Hertzian Waves	Infra-red Rays	Visible Rays
Generation for medical and biological uses	Discharge of condensers; short electric wave generators	Electric radiator, carbon filament lamp, arc	Incandescent filament lamp; arcs
Biological and medical applications	High frequency; diathermy	Thermotherapy; calorotherapy	Phototherapy
Action on skin	With diathermy, through heating	Immediate hyperemia	No hyperemia if infra-red and ultra-violet are removed
Rate of ordinary reaction	Immediate	Immediate and soon fading	No reaction if pure visual rays
Effect of overdose	Destruction of tissue	Destruction of tissue	Superficial effect; no destruction of tissue
Action on body	Vaso-dilatation and heating	Hyperemia; elevation of temperature and de-congestive effects	Visual effects chiefly; claimed to increase hemoglobin
Action on plants	Increases growth	Increases growth	Increases growth
Effect on bacteria	May change metabolic activity and other characteristics	Abiotic above certain temperatures	None, unless sensitizing substances, such as eosin, are used

RADIATIONS OF THE ELECTROMAGNETIC SPECTRUM

Ultra-violet Rays	. Roentgen Rays	Gamma Rays	Cosmic Rays
Carbon arcs, mercury vapor lamp	X-ray bulbs	Radium with suitable filters	
Actinotherapy	Roentgen therapy	Radium therapy	
Hyperemia after a latent period of a few hours	Hyperemia after a latent period of several days	Very lasting hyperemia after latent period	
After latent period of several hours	After latent period of about 10 days	After latent period of about a month; reaction quite permanent	
Largely superficial effects	Destruction of tissue	Destruction of tissue	
General tonic effect; increased calcium and phosphorus absorption and normal formation of bone	Destruction of cells, especially young active cells	Destruction of cells, especially young or very active cells	
Decreases growth in general when plants are in normal environment	Very small doses may be stimulating; in general destructive	Decreases growth	
Abiotic, and in general destroying toxins and anti-toxins	Little or no action	Has slower action than ultra-violet rays	

Jeans (Man and the Stars) wrote: "This radiation is the most fundamental physical phenomenon of the whole universe. It is so intense that it breaks up several millions of atoms in our bodies every second. It may be essential to life or it may be killing us."

III. BIOLOGIC EXPERIMENTS ON THE INFLUENCE OF RADIANT ENERGY ON CALCIUM AND PHOSPHORUS METABOLISM AND THE GROWTH AND DEVELOPMENT OF PARATHYROID GLANDS

There is a wealth of experimental evidence from both the animal and the clinical standpoint to substantiate the fundamental value of ultra-violet irradiation in the prevention and cure of certain types of disease and to demonstrate its role in growth and nutrition (Fig. 5). By reason of this wealth of experimental work, I shall present only some of the data and conclusions reached from the researches of my colleagues and me.

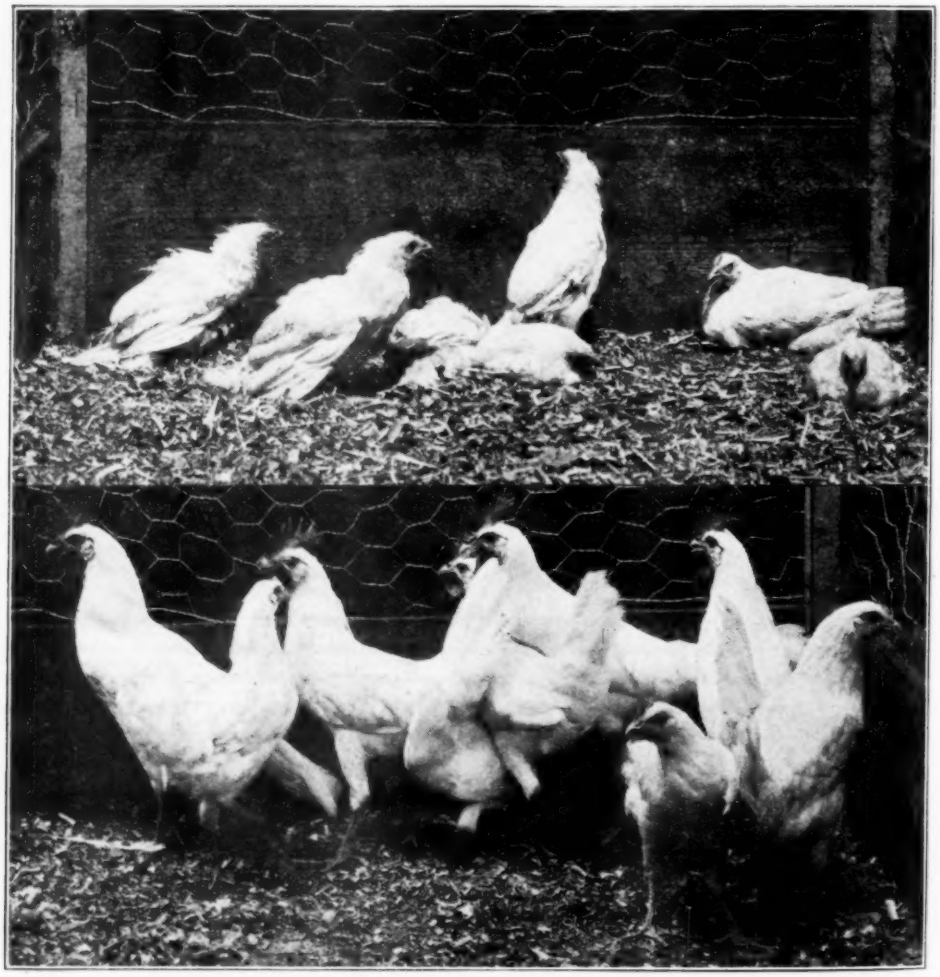

Fig. 5. Growth and development with and without vitamin D or ultra-violet light. These chickens, of the same hatching, had the same diet: those in the upper picture received no vitamin D or ultra-violet light, whereas those in the lower picture had plenty.

Effects of Winter Solar Irradiation and of Cod Liver Oil on the Production and Fertility of Eggs—Hart, Steenbock, and their colleagues (*Journal of Biological Chemistry*, 65: 519-595, Oct., 1925) had previously demonstrated that irradiation of hens with ultra-violet light results in abundant production of eggs, increases the lime in the shell and sustains hatchability at from 60 to 70 per cent. They found that the embryos from the eggs of irradiated hens contained nearly twice as much lime as those from non-irradiated hens. Higgins and I (*Proceedings Society Experimental Biology and Medicine*, 27: 467-474, Feb., 1930) carried on experiments with a colony of hens and cockerels divided into three equal groups. Group 1 was housed behind ordinary window glass with 2 per cent by weight of cod liver oil (Squibb's) added to the diet; group 2 was housed behind quartz-containing glass (vitaglass), and group 3 was housed behind ordinary window glass only. The diet fed throughout the experiment, which lasted from November to the following May, was the standard Wisconsin all-mash ration. We concluded that:

1. Sufficient ultra-violet light is transmitted by such quartz-containing glasses as vitaglass or helioglass in the winter months in Minnesota to keep the production and fertility of eggs at a high level.

2. Ordinary window glass screens out from winter sunlight radiation which is beneficial to the maintenance of high production and fertility of eggs.

3. It appears that these results are due either to the transmission of solar energy in the region of 290 to 320 millimicrons or to the greater transmission of the ultra-violet rays (from 320 to 400 millimicrons) of sunlight by quartz-containing glass.

4. The addition of 2 per cent of cod liver oil to the standard Wisconsin ration gives results the equal of or slightly superior to those obtained with winter sunlight passed through an ultra-violet transmitting medium.

5. From these experiments and from those of other investigators, there is evidence that the presence or absence of the antirachitic factor vitally affects the production, fertility and hatchability of eggs.

Effects of Selective Solar Energy, With and Without Supplementary Irradiation, on the Growth of Chicks and the Development of Parathyroid Glands—Higgins and I (*American Journal of Physiology*, 85, 290-298, June, 1928; also 85, 299-310, June, 1928) reported the results of investigations on the growth of chicks and the development of the parathyroid glands. In these experiments, chicks were placed in compartments which had windows with a southern exposure, fitted with about 10 square feet of amber, blue and ordinary glass and quartz-containing glass (vitaglass), respectively. Half of the chicks under each filter were fed the Wisconsin basic all-mash ration (deficient in vitamin D only). The other half were fed this ration plus 2 per cent by weight of cod liver oil. Hyperplastic glands and subnormal weights were found within the first few weeks in chicks which were

kept under the amber or blue filters when they were on the basic diet only. Normal glands and normal weights occurred in chicks which grew under quartz-containing glass (vitaglass). Normality both in parathyroid glands and weights was obtained under all the selective spectral filters when 2 per cent by weight of cod liver oil was added to

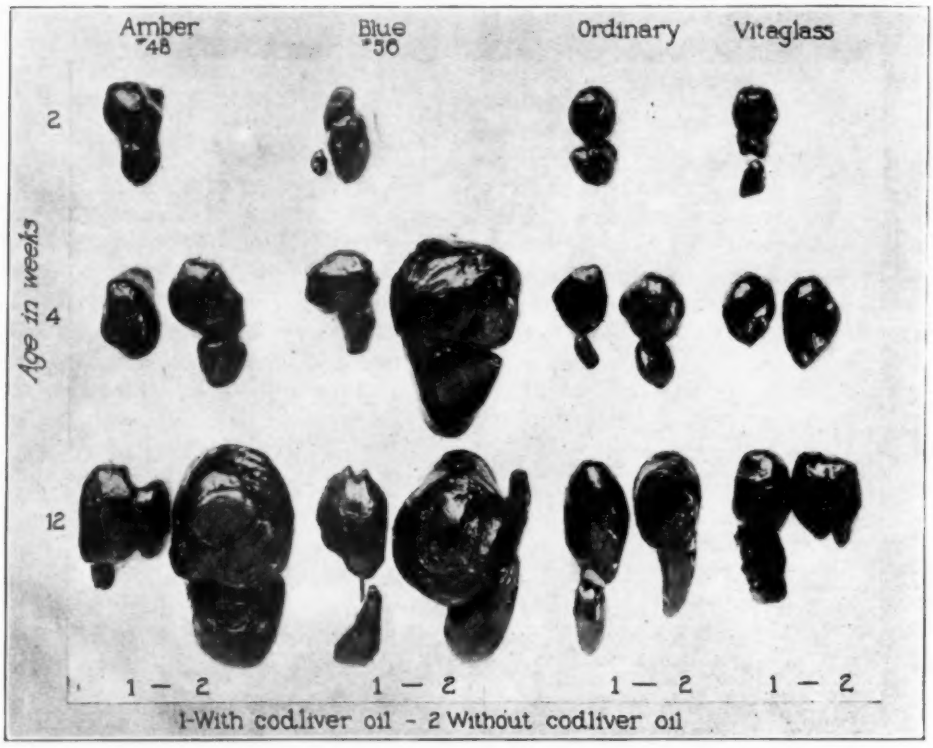

Fig. 6. A series of models of the parathyroid glands of chickens grown under the spectral glass filters named with and without administration of cod liver oil (X 50). The numeral 1 indicates that 2 per cent (by weight) of cod liver oil was added to the diet. In 2 the standard diet only was fed (Higgins and Sheard, *American Journal of Physiology*, 1928).

the diet (Fig. 6). From these experiments, it was concluded that there was evidence to support the statement that (1) cod liver oil (2 per cent by weight added to the diet adequate in all ingredients except vitamin D) is able to induce normal growth of chicks and of the parathyroid glands irrespective of the presence or absence of any portion of either ultra-violet or visible solar energy, and (2) normal growth and development of chicks and of the parathyroid glands, when the chicks are fed on a diet deficient in vitamin D, are dependent on both the ultra-violet and visible portions of solar radiation, all other factors remaining constant so far as is known.

In order to put to further test the statement that normal growth and development of chicks and parathyroid glands are dependent both on ultra-violet and longer visible portions of radiant energy, Higgins, Foster and I (*American Journal of Physiology*, 94: 84-90, July, 1930; also 94: 91-100, July, 1930) carried on a second series of investigations in which we attempted to compensate for the absence of the shorter ultra-violet wave-lengths of solar radiation (which are not transmitted by amber glass) through daily exposure of the chicks, constantly housed behind amber glass, to the radiant energy from an air-cooled quartz-mercury lamp for five, ten and fifteen minutes, respectively. In addition, two groups of chicks were housed behind purple corex glass (Corning Glass Company, G986A, 5 mm. thick), which transmits practically no visible light, but does transmit a goodly portion of the ultra-violet region (maximal transmission of 20 per cent at 330 millimicrons, the limits of transmission lying between 290 and 400 millimicrons).

If, then, energy in the ultra-violet region of sunlight, especially energy in the region of the so-called vita rays (from 290 to 320 millimicrons) is sufficient, in and of itself, to induce normal growth and development of chicks and of the parathyroid glands, it would appear that constant housing of chicks behind corex windows with a southern exposure should produce normality in growth, as evidenced by weight, and in the development of the parathyroid glands. Again, if both the visible and ultra-violet portions of solar energy are necessary for normal growth and glandular development, it would appear that sufficient supplementary irradiation by sources rich in ultra-violet radiation should cause development of normal conditions in chicks constantly housed behind amber glass filters. Without explaining the details of the experimental work and results, it may be stated that (1) irradiation with the air-cooled quartz-mercury arc lamp for ten minutes daily, of the entire bodies of chicks, constantly housed behind amber filters, induced normal growth and development of chicks and of the parathyroid glands, (the energy of the ultra-violet irradiation in the region from 260 to 320 millimicrons received from the quartz-mercury arc, operated at 90 volts and a distance of 50 cm., during ten minutes is about 110,000 ergs for each square millimeter), and (2) the daily reception of ultra-violet energy in the vita region (from 270 to 320 millimicrons), amounting to 125,000 ergs for each square millimeter transmitted to the chicks through corex, produces approximately normal weights but permits hyperplasia, cystic degeneration and fibrous invasion of the parathyroid glands.

Under the experimental conditions employed, grade of stock used and ration fed in these investigations, we expressed the belief that:

1. Constant housing of chicks behind an amber glass filter, which transmits only the longer visible wave-lengths of sunlight, definitely retards growth and development and allows hyperplasia, cystic degeneration and fibrous invasion of the parathyroid glands.

2. Constant housing of chicks behind a filter (red-purple corex glass) which transmits practically only the ultra-violet region (from 270 to 400 millimicrons), with maximal transmission of 20 per cent at 330 millimicrons, rarely permits normality in development and growth of chicks as evidenced by weight, and it induces hyperplasia, cystic degeneration and fibrous invasion of the parathyroid glands.

3. Normal weights and normal development of parathyroid glands are found in chicks constantly housed behind an amber filter and given daily supplementary irradiation for ten to fifteen minutes with an air-cooled quartz-mercury lamp operated at 90 volts and at a distance of 50 cm. (ultra-violet irradiation of approximately 575 ergs each square millimeter).

4. Normal calcification of bones (as evidenced microscopically by the Becke method and by determining the percentage of calcium by weight) and normal weight of chicks resulted under several of the experimental conditions imposed relative to quality and quantity of energy, with, however, the presence of abnormal parathyroid glands. Therefore, the absence of evidence of rickets or of malnutrition does not argue for normality of parathyroid glands.

5. Further evidence is presented, therefore, to support the statement that normal growth and development of chicks and of the parathyroid glands are dependent both on the ultra-violet and visible portions of solar irradiation, all other factors remaining constant as far as is known.

My latest researches with Higgins (as yet unpublished) indicate that from twenty to thirty minutes of noon-day sun in the summer is sufficient to prevent the development of rickets, but that about twice this quantity of solar irradiation is necessary in order to produce normal parathyroid glands. In the middle of winter, about five times as much, or from two to five hours' exposure to outdoor sunshine would be necessary. As far as chickens are concerned, about twenty minutes' daily irradiation with ultra-violet light (90 volts, 6 amperes, and at a distance of 50 cm.) is sufficient to compensate for the absence of ultra-violet rays in the environment of chickens housed behind filters which absorb the ultra-violet in the so-called vita region (from 290 to 320 millimicrons).

IV. THE GERMINATION OF SEEDS, GROWTH OF PLANTS AND DEVELOPMENT OF CHLOROPHYLL AS INFLUENCED BY SELECTIVE SOLAR RADIATION

The energy in sunlight ranges from the infra-red (or heat) rays, through the visible from red to violet and on into the ultra-violet—the short rays of sunshine so necessary to prevent rickets. Are each of these regions of solar energy equally necessary as aids to germination, development, growth and maintenance of existence, or do quality (wave-length) and quantity (intensity) of energy enter as important

factors? Are certain wave-lengths and intensities of radiant energy used by plants for one purpose, while other regions and intensities of energy perform a distinctly different function and service? Do certain wave-lengths of solar radiation promote growth, while other regions of solar energy retard it? Is the development of chlorophyll chiefly dependent on the infra-red, visible or ultra-violet rays?

Sheard, Higgins and Foster (*Science*, 71: 291-293, March 14, 1930) endeavored to answer these and similar questions by making physical measurements on the quality (wave-length) and quantity (intensity) of the radiant energy used, the amounts of chlorophyll developed and so forth and by conducting biological experiments on the number of germinations, heights and weights of plants and areas of leaves.

Effects Produced Under Quartz-containing Glass, Ordinary Window Glass, Amber and Blue Glass Filters—Quartz-containing glass transmits the whole of the visible portion and a very considerable part of the ultra-violet region of sunlight; ordinary window glass deletes the shorter ultra-violet wave-lengths in large part; amber glass transmits only the longer wave-lengths while blue glass transmits only the shorter visible and longer ultra-violet wave-lengths of incident radiant energy.

Employing Pittsburgh amber No. 48, Pittsburgh blue No. 56, vitaglass (quartz-containing glass) and ordinary window glass, the experiments of Sheard, Higgins and Foster have shown: (1) In general, the number of germinations is the greatest under vitaglass or ordinary window glass, comparable under the blue filter and least under the amber glass. (2) The average height of stalks increases as we pass from the plants grown under ordinary window glass to vitaglass, to the blue filter and finally to the amber glass. (3) The areas of the leaves are the greatest under vitaglass, less under ordinary window glass, still less under the blue filter and least under amber glass. (4) The weights of plants (stalks and leaves) as grown under the four filters are in the order: vitaglass, amber, blue and ordinary window glass. (5) The lengths and weights of the roots are of the same order of magnitude and arranged in the same sequence as the lengths of stalks and weights of plants. (6) The development of chlorophyll for each gram of plant (not dried) is greatest under vitaglass and decreases in the sequence of ordinary window glass, blue and amber filters.

A comparison of these biological results with the data regarding the percentages of various types of solar radiation transmitted to the plants indicates that the growth is greater under either the longer or shorter wave-lengths of sunlight than it is under the full complement (practically) of sunlight. The infra-red transmissions of the four filters are comparable, therefore this region of solar radiation does not appear to be the controlling factor. Furthermore, the growth under amber or blue filters, which transmit from 30 to 40 per cent only of

the visible portion of sunlight, is greater than under vitaglass or ordinary window glass which transmit about 90 per cent of the incident visible light. The growth is greater, therefore, under a portion of solar radiation than it is under the full complement of sunlight. A spectrophotometric study of the amber and blue filters shows that there is a relatively small transmission of energy in the green region of the spectrum. The inference (which is substantiated quite definitely by the experiments under the group of seven Corning glass filters) may be drawn that the green region of the solar spectrum, which is the region of maximal energy of sunlight, is inhibitory in character so far as growth is concerned. Or we may say that the infra-red and red regions of sunlight, at one end of the spectrum, and the blue, violet and ultra-violet at the other extreme of the solar spectrum, are vital and stimulating to growth. The development of chlorophyll, however, is practically the same under the amber or blue filters but is greatest under vitaglass or ordinary window glass. From these experiments, in which vitaglass, window glass, blue and amber filters were used, it can not be stated, however, whether or not the development of chlorophyll is dependent on the total quantity of energy transmitted by the filters or on the quality (presence or absence of certain wavelengths) of the incident radiant energy.

Effects Produced Under Spectral Filters Transmitting Chiefly One Quality Only of Radiant Energy—In order to limit more narrowly the quality and quantity of solar radiation incident on any group of seeds or plants we have used a set of special filters (Corning Glass Company 586A, 586AW, 585, 584J, 34Y, 24, 554FF and 392H) which transmit chiefly ultra-violet, violet, blue, green, yellow, red and infra-red rays respectively (Fig. 7).

Under these experimental procedures the results indicate that: (1) The number of germinations is greatest under the infra-red and ultra-violet portions of sunlight and least under the green region. (2) The average height of stalks is greatest in the infra-red and red regions at the one extremity of the solar spectrum and in the violet and ultra-violet portions at the other extremity of the spectrum, and least under the green and heat-absorbing filters, as shown in Figure 7. (3) The average weight of plants follows the same sequence as stated with reference to the average height of stalks. (4) The development of chlorophyll is greatest under the infra-red and ultra-violet radiations.

A comparison of data relative to the quality and quantity of incident energy with the biological effects observed shows that a proportionately small percentage of ultra-violet light (since the ultra-violet content of sunlight is about 10 per cent only, the visible 15 per cent and the infra-red 75 per cent) is as efficacious as the infra-red rays, if not more so, in stimulating and promoting germination and growth.

These observations are substantiated further by the results obtained by Sheard and Johnson (*Science*, 71: 246-248, Feb. 28, 1930) on the changes in electrical potentials and currents produced in plants

Fig. 7. Photograph of the effects of selected portions of solar radiation on the growth of beans, other factors remaining constant in so far as known. See legends. page 108.

by various types of radiant energy. In their experiments it was found that marked changes in potential differences (voltage) were produced by ultra-violet and infra-red radiations and that the electric currents obtained in leaves, when an external but constant electromotive force was impressed, were increased by both these types of radiant energy. Furthermore, these changes in potential differences between the base and the tip of leaves were found to be associated very definitely with the phenomenon of growth. No changes in potential differences or in electric currents were produced by the visible portions of sunlight or various artificial sources of radiation.

The development of chlorophyll is dependent chiefly on the quality of the incident radiant energy, namely, the energy in the green region of the visible spectrum. Little chlorophyll is found in plants grown under filters which transmit infra-red or ultra-violet rays only. A comparison of the energy of the incident light transmitted by these filters and measured with thermopiles shows that a transmission of

5 per cent of the green region (through a green filter) produces a greater amount of chlorophyll for each gram of plant than is produced by a transmission of 40 per cent of energy in the yellow or red regions of solar radiation obtained through yellow and red filters.

From these and similar experiments it may be concluded that:

(1) The ultra-violet and infra-red portions of sunlight are stimulating to germination and enhance growth and development.

(2) The green portion of the solar spectrum, which is its region of maximal energy, is inhibitory to the processes of germination and growth.

(3) The development of chlorophyll is enhanced under the yellowish-green, green and greenish-blue regions of the spectrum.

(4) The least development of chlorophyll occurs under the ultra-violet and infra-red portions of the spectrum.

V. SOME EFFECTS OF RADIANT ENERGY ON THE EYE

The extent of our knowledge of the influence of radiant energy of specific kinds and amounts on the human eye and hence, indirectly, on the comfort and efficiency of human vision is as yet very limited. We have, for example, two rather divergent and apparently conflicting ideas as to the influence of radiant energy in the production of cataract. Both of these views may be found to be compatible, however, for either the infra-red or the ultra-violet may superinduce cataract under certain physiologic conditions.

Some years ago, Burge (*Transactions Illuminating Engineering Society, 1915*) carried out a series of experiments on cataracts produced in the eyes of fish living in water containing small percentages of calcium chloride or sodium silicate (Fig. 8). It is well known that cataracts are extremely common in the natives of India and, in general, in people living in the tropics. Chemical analyses show the presence of

Fig. 8. (Refer to legends, page 108.)

large quantities of silicates in the cataractous lenses of the people of India, but no appreciable silicates are found in those from the United States. Silicates may be accounted for in part by the fact that certain

sects or classes in India eat siliceous earths as part of their diet, while the prevalence of cataract may be accounted for by the large amount of ultra-violet radiation present in tropical sunshine and the silicates present in the media of the eye. Burge has, therefore, endeavored to correlate the interaction of ultra-violet light, the proteins of the lens and chemical salts in accounting for cataract. His experiments show quite conclusively that there is added liability to cataractous conditions when certain salts are in excess in the nutritive sources of the lens.

The short wave-lengths of the spectrum produce a molecular rearrangement in the protoplasm of the cells of the crystalline lens, so that inorganic salts, such as are found to be greatly increased in cataractous lenses in man, can combine with the protoplasm to precipitate it, and hence produce an opacity

That ultra-violet radiations kill living cells by coagulating their protein may be seen by direct observation through the microscope during an intense exposure of unicellular organisms, such as paramoecia.

The effective region of the spectrum in changing the living material of the cell or protoplasm lies between 254 millimicrons and 302 millimicrons. The most effective region is around 254 millimicrons for the small quartz-mercury burner used, and around 302 millimicrons for the large burner.

An opacity of the lens, or cataract, can be produced in fish living in solutions of those salts found to be greatly increased in cataractous lenses in man by exposing the eye of the fish to radiation from a quartz-mercury vapor burner. This cannot be done by exposing the eyes of fish living in tap water, which contains only very small quantities of these salts (see Fig. 8).

Abnormal quantities of the salts of calcium and sodium silicate in the cells of the eyelid and of the cornea increase the effectiveness of ultra-violet radiation in producing trouble in these structures. Abnormal quantities of calcium salts in the skin presumably increase the effectiveness of the short wave-lengths in sunlight in producing sunburn.

In looking for the cause of cataract it would seem that at least two factors should be considered: The one, a modification of the protein of the lens by ultra-violet radiation, and the other, the presence of certain inorganic salts by which the modified protein can be precipitated. According to this hypothesis, the prevalence of cataract among people living in the tropics could be accounted for by the increase in the radiant energy factor modifying the lens protein so that an excess of salts, such as silicates in case of people in India, would combine with the protein to precipitate it and produce opacity of the lens, or cataract. The prevalence of cataract among glass-blowers is also accounted for by the excess of the radiant energy factor, the assumption being that glass-blowers who develop cataract have, independent of their work, a more or less disturbed condition of nutrition, expressing itself as an increase in sugar (as the result of diabetes), in calcium salts or in some other substance, which can combine with the lens protein made sensitive by the action

of the short wave-lengths of light to which glass-blowers are exposed in their work.

The chief conclusions of Verhoeff and Bell (*Proceedings American Academy of Arts and Sciences*, 51, No. 13, 1916) relative to formation of cataract and other effects of irradiation on the eye are:

1. Abiotic (lethal) action for living tissues is confined to wave-lengths shorter than 305 millimicrons. The lens protects the retina of the normal eye completely even from the small percentage of abiotic rays which can penetrate the cornea and vitreous humor. To injure the cornea, iris and lens by the thermic effects of radiation requires extreme concentration of energy. No concentration of radiation on the retina from any artificial illuminant is sufficient to produce injury thereto.

2. Snow-blindness may occur after long exposures to ultra-violet light. Glass-blower's cataract is not due to ultra-violet rays but probably to the overheating of the eye as a whole with consequent disturbance in the nutrition of the lens.

3. Commercial illuminants are entirely free of danger under the ordinary conditions of their use. The glass globes are sufficient to prevent any deleterious effects due to ultra-violet.

4. Suitable glasses protect because they reduce the total amount of light to a point where it ceases to be psychologically disagreeable or to be inconveniently dazzling.

There are also the researches of Hartridge and Hill, of England, in which the seat of the irritation leading to cataractous conditions may be attributed in many cases to the infra-red or the longer wave-lengths of radiant energy. Such radiations are freely transmitted by the cornea and are absorbed in large part by the iris which lies close to the lens. They may thus cause nutritional changes in the lens by virtue of the abnormal stimulus to the processes controlling the secretion of the humor. Such a view seems entirely reasonable and highly probable. It may be accepted, therefore, as definitely proved, that radiant energy, either by virtue of its kind or its quantity, may aid in or be the primary cause of cataractous formations when certain physiologic conditions are present.

Hartridge and Hill (*Proceedings Royal Society of London*, Series B, 89, 1913) expressed the belief that heat radiation is probably absorbed slightly by the pigment in the substance of the iris, by far the greater amount of energy passing through and being absorbed finally by the pigment on its posterior surface. In the case of blue-eyed persons the pigment in the stroma of the iris is absent and the posterior pigmentary layer is alone effective in absorbing radiant energy. This means that the absorbent layer comes in intimate contact not only with the posterior chamber of the eye but also with the processes of the ciliary body themselves. A rise in the temperature of the pigmentary layer due to the absorption of heat must necessarily cause at the same time a rise of temperature by conduction to surrounding structures; in this the glandular

elements of the ciliary body take part, and there is excessive secretion of aqueous humor which nourishes the lens.

There are several remarkable features in the occurrence of glass-blower's cataract. The very long period taken for the condition to develop does not at all suggest any pathologic change of an inflammatory character; nor has any obvious change in any other structure of the eye apart from the lens been described. Thus the pupil is normal in size and reaction to light, which would not be the case if it had been the seat of any chronic inflammatory change. It would seem more likely, therefore, that the change in nutrition of the lens is one brought about by some physiologic alteration in the secretory mechanism of the aqueous humor rather than by a pathologic change. One needs only to postulate a secretion of aqueous humor when heat falls on the iris to obtain what appears to be a plausible hypothesis of the formation of the cataract. Normally, aqueous humor is secreted in small amounts all the time; when heat falls on the iris a larger secretion occurs. This stimulus, occurring regularly over long periods of time, ultimately causes the secretory mechanism to be more and more dependent on the external stimulus. The secretion becomes periodic in character so that the lens, instead of receiving nourishment continuously, gets it only at intervals, with the result that the least well-nourished part of the eye suffers and cataract develops.

In this presentation I have emphasized the possible role of radiant energy in the production of cataract. Equal emphasis should be laid, in all probability, on the nutritional phases, especially as they are influenced by certain salts. Investigations show that calcium has an important influence. In recent years we have learned that the parathyroid glands control the metabolism of calcium. Disturbances of the parathyroid glands and their functions have been observed in association with tetany and with cataract which may be an accompaniment of tetany. The best evidence is to the effect that glass-blower's cataract is due to infra-red or heat. Whether it is the effect of heat *per se* which reaches and is absorbed by the lens or whether it is the effect of heat on the nutritional processes of the eye is not known definitely. On the other hand, the absorption of ultra-violet light and its possible degradation into energy of longer wave-lengths, as is shown by the phenomenon of fluorescence, or the change of the energy of the light absorbed by the iris and the choroid into heat, may have considerable bearing on cataract and other changes in the eye.

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(Bibliography on page 108)

LEGENDS

Fig. 7. Photograph of the effects of selected portions of solar radiation on the growth of beans, other factors remaining constant in so far as known.

Left to right: (1) Filter 586 A—ultra-violet and violet, (2) 586 AW—ultra-violet and violet, (3) 585—chiefly violet and blue, (4) 584 J—chiefly green—with blue and yellow in much smaller amounts, (5) 34 Y—yellow, orange and red, (6) 24—orange and red, (7) 554 FF—infra-red with no visible radiation, (8) normal sunlight (After Sheard, Higgins and Foster).

Fig. 8. Fish (1) living in tap water and exposed to ultra-violet radiation for 12 hours; no effect. Fish (2) living in 0.1 per cent sodium silicate and exposed to ultra-violet radiation for 12 hours; evidence of formation of cataract. Fish (3) living in 0.1 per cent sodium silicate and exposed to ultra-violet radiation from the same source for 24 hours; definite cataract (After Burge, *Transactions Illuminating Engineering Society*, 1915).

BIBLIOGRAPHY

Allen, H. S.: Electrons and Waves. Macmillan and Co., 1932.
Blunt, K. and R. Cowan: Ultra-violet Light and Vitamin D. University of Chicago Press, 1930.
Bose, Sir J. C.: The Physiology of Photosynthesis. Longmans, Green and Co., 1924.
Clark, J. T.: Lighting in Relation to Public Health. Williams and Wilkins Co., 1924.
Duke-Elder, W. S.: Recent Advances in Ophthalmology. P. Blakiston's Son and Co., 1927.
Ellis, Carleton and A. A. Wells: The Chemical Action of Ultra-violet Rays. The Chemical Catalogue Co., 1925.
Hill, Leonard: Sunshine and Open Air. Edward Arnold and Company, London, 1925.
Humphris, F. H.: Artificial Sunlight and Its Therapeutic Uses. Oxford University Press, 1926.
Leutz, C. R., and R. B. Gable: Short Waves. C. R. Leutz, Altoona, Pa., 1929.
Luck, J. M. (Editor): Annual Review of Biochemistry. Stanford University Press, 1932.
Luckiesh, Matthew: Ultra-violet Radiation. D. Van Nostrand Co., 1922.
Luckiesh, Matthew: Artificial Sunlight. D. Van Nostrand Co., 1930.
Luckiesh, M., and A. J. Pacini: Light and Health. Williams and Wilkins Co., 1926.
Matthews, A. P.: Physiological Chemistry. 4th Ed. Wm. Wood and Co., 1925.
Mayer, Edgar: Chemical Applications of Sunlight and Artificial Radiation. Williams and Wilkins Co., 1926.
Millikan, R. A.: The Electron. University of Chicago Press, 1926.
Palladin, V. I.: Plant Physiology (Translated by B. E. Livingston). P. Blakiston's Son and Co., 1926.
Peirce, G. J.: The Physiology of Plants. Henry Holt and Co., 1926.
Russell, E. H., and W. K. Russell: Ultra-violet Radiation and Actinotherapy. 3rd Ed. William Wood and Co., 1928.
Sheard, Charles: Transmission of Radiant Energy by Ophthalmic Glasses. Cleveland Press, 1921.
Sheard, Charles: Life Giving Light. Williams and Wilkins Co. (To be published in 1933).
Spoehr, H. A.: Photosynthesis. Chemical Book Catalogue. 1926.
Steinmetz, C. P.: Radiation, Light and Illumination. McGraw-Hill Book Co., 1909.
Stiles, Walter: Photosynthesis. Longmans, Green and Co., 1925.
Terrill, H. M., and C. T. Ulrey: X-Ray Technology. D. Van Nostrand Co., 1930.
Valasek, Joseph: Elements of Optics. McGraw-Hill Book Co., 1928.
Weatherwax, J. L.: Physics of Radiology. P. B. Hoeber, 1931.
Woodruff, C. E.: Medical Ethnology. Rebman Company, 1915.

AN INTERESTING CASE OF ACQUIRED EYE TIC*

H. Leslie Salov, Opt.D.
Newark, N. J.

Patient: Master B. L., age 9, school boy.

History: Master B. acquired a habit of jerking his head to the right side and closing the right eye. The patient is a healthy child, a good student in school and was desirous of ridding himself of this habit.

Externals: N. V. A. R. E. 20/20. L. E. 20/20. Pupils react to light directly and consensually. They react to accommodation with good amplitude and quality.

Ophthalmoscopy: Both eyes negative.

Refraction: Emmetropia.

Innervational Tests: Phorias and ductions, normal relationships.

Diagnosis: An acquired habit of eye tic.

Remarks: On questioning the patient, we found that he had first started to imitate some boy in the classroom who turned his head and

Record of Head Jerks and Shutting Right Eye

Week of March 5, 1933		Week of March 19, 1933	
Sunday	14	Sunday	6
Monday	15	Monday	5
Tuesday	12	Tuesday	6
Wednesday	12	Wednesday	5
Thursday	12	Thursday	4
Friday	11	Friday	5
Saturday	13	Saturday	2
Week of March 12, 1933		Week of March 26, 1933	
Sunday	14	Sunday	1
Monday	16	Monday	1
Tuesday	17	Tuesday	1
Wednesday	14	Wednesday	0
Thursday	18	Thursday	0
Friday	13	Friday	0
Saturday	11	Saturday	0

*Submitted for publication January 31, 1934.

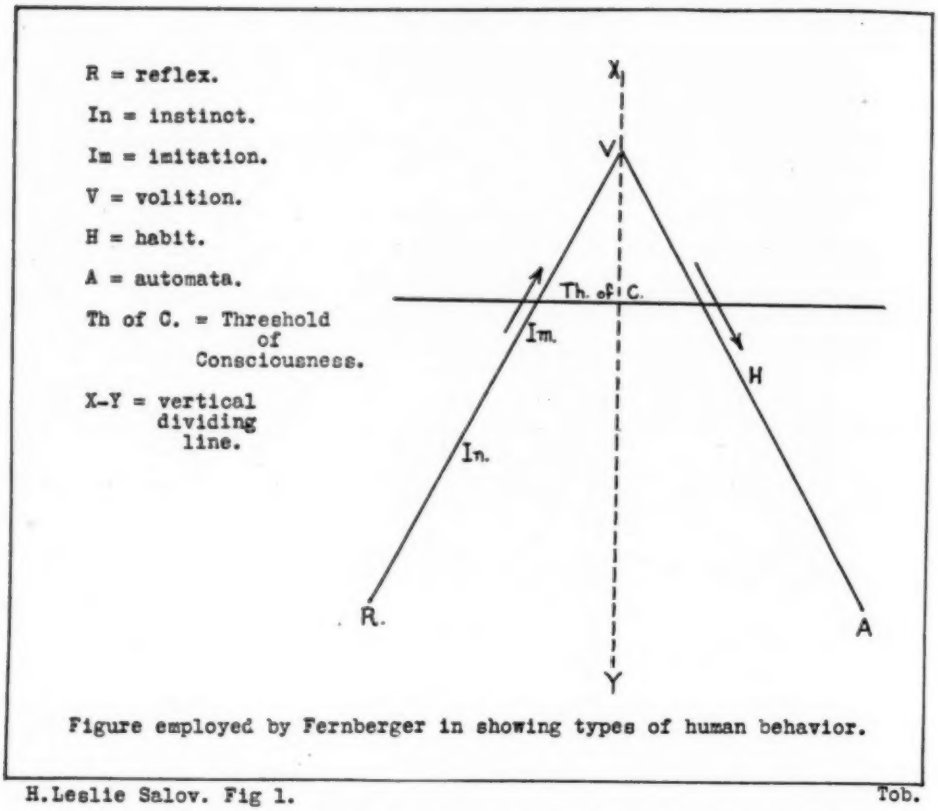

Figure employed by Fernberger in showing types of human behavior.

H.Leslie Salov. Fig 1. Tob.

closed his eye continuously throughout the school-day. After imitating him for a week, the act was done unconsciously.

Treatment: To remove this habit it was necessary to make the child conscious of every time he turned his head and closed his eye. "Any habitual act, in order to be removed, must be lifted to a higher level, making of the habitual act a consciousness-accompanied performance, in which case it finally becomes willed performance and when the motivation for its performance is wanting, it is lost as routine behavior," according to Doctors Twitmyer and Nathanson of the Psychological Department of the University of Pennsylvania in their book, "Correction of Defective Speech." The patient was instructed to supply himself with a small notebook, to be carried with him always, with a page for each day of the week and to record every time he did this act. Below is a copy of the pages kept by the patient showing the progress of the treatment. In five weeks the habit disappeared.

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A CASE OF ASTIGMIA OF LARGE AMOUNT*

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Readers of the AMERICAN JOURNAL OF OPTOMETRY may be interested in an astigmatic case for whom we prescribed a very unusual pair of glasses with most gratifying results. The patient, now a retired railroad man, came to me for a correction twelve years ago. He was then 39 years of age. The glasses prescribed at that time were:

O. D. —1.50 D. Sph. ⊃ + 6.00 D. Cyl. axis 180 ⊃ 3Δ base down.

O. S. —6.00 D. Sph. ⊃ + 12.00 D. Cyl. axis 180 ⊃ 3Δ base out.

These glasses gave the patient perfect vision in both eyes and were in every way satisfactory for both distance and near point work until of late. At the time this was prescribed this correction was the strongest prescription I had written during the twenty-five years I had been practicing.

This same patient returned to me for a new correction about two months ago. After a very complete examination I was surprised to find the following correction necessary:

O. D. —2.00 D. Sph. ⊃ + 8.00 D. Cyl. axis 180.
O. S. —8.00 D. Sph. ⊃ + 17.00 D. Cyl. axis 175.

No prism seemed necessary and the correction was prescribed as written. The patient has worn this formula for the past two months with comfort, having normal vision and for all practical purposes an orthophoria. It was necessary, however, to give the patient a pair of +2.00 D. Sph. in a grab front frame to assist him at his near-point work.

As far as the left eye of this patient is concerned, the correcting lens, a —8.00 D. Sph. ⊃ + 17.00 D. Cyl. axis 175, is the strongest combination that I have ever heard of, and what makes this even more remarkable is that his visual acuity with this correction in place is normal. This pair of lenses was made at Southbridge by the American Optical Company after special tools had been prepared to grind the combination.

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A SIMPLE MONOCULAR DEPTH PERCEPTION TEST

In an effort to devise some simple method of testing the remaining monocular depth perception of individuals who have suffered the loss of vision of one eye, Pickard[1] devised the following simple apparatus and technic:

The test is naturally monocular. The apparatus consists of a cork dinner-mat about eight inches in diameter, the front of which is covered with black velveteen. To this front surface are stuck thirty or any other convenient number of pins of varied length. These ranging from three inches to 3/8 inch in length. On the head or blunt free end of each pin is affixed some sealing wax of different colors. These colors should be bright, therefore being easily distinguished from one another. The pins actually used by Pickard were 6 yellow headed pins, 6 red, 6 green, 6 dark blue and 6 white, a total in all of thirty pins with colored heads. Each color was placed on the heads of pins of different length.

Pickard's technic was as follows: He held the disc upright some two feet in front of the patient, who was given a full length lead pencil. Holding this pencil in his working hand (usually the right hand), the

[1]R. Pickard. Depth Perception Test. E. E. N. and T. Monthly. Vol. 13, No. 1, page 37.

patient was told to touch all pins of a particular color, e.g., red, with the blunt end of the pencil. While doing this the patient was instructed to keep his head perfectly still. The test was then repeated with each of the other five colors. While the test was in progress the accurate number of good contacts for each color was noted and the totals were added together at the end of the test.

Pickard found from testing a number of monocular patients who were able to carry on their vocations successfully that twenty-five correct contacts out of a possible thirty were usually obtained and he took this figure as a standard. If the patient obtained this number it was assumed that his remaining depth perception was normal. To score a perfect contact the head of the pin must be hit fairly, a glancing blow did not count.

It should be noted at this point that as far as the patient is concerned, the test is a color test but to the examiner it is a depth perception test. If by chance the patient should be color blind, this really does not matter, as his hits and misses can be recorded as usual. Of course, no hint of the real object of the test can be given to the patient, otherwise the malingerer would score many intentional misses and the neurasthenic patient would reveal his neurasthenia rather than his depth perception.

In his work, Pickard finds the real difficulty of those who have recently lost an eye is in the anterior-posterior dimension of depth perception. In the lateral and vertical angle dimensions the sensations from the external ocular muscles added to the movements of the images of the objects viewed over the retinal fields are sufficient guides. It is for this reason that the patient's head must not move in making the test, and also that the patient must move the pencil directly towards the pin head and not in towards it from one side or another.

The apparatus just described is simple and inexpensive to make. It could be varied by a greater variety in the length of the pins and in the kind of pointer used to hit or contact the pin-heads. However, if any variation is made, care must be taken to again obtain the average or normal proficiency by testing a number of monocular individuals who are known to be carrying on craft occupations successfully. C. C. K.

* * * * *

DIAGNOSIS AND SYMPTOMS

It is so easy to permit the limited barriers of ones own specialty to obscure, in certain cases, the underlying cause for the defect that we must at all times be diligent in guarding against so doing. While it may be true that most persons who call in an optometrist for relief from ocular or what seem to be ocular symptoms are able to get this relief through the strait correction of existing ocular defects, cases do arise from time to time in which the ocular symptoms complained of by the patient are but manifest symptoms, the fundamental cause lying elsewhere.

A case fully illustrating this point was recently presented by Wilbur and Eusterman.[1] They were called in to examine a patient who complained of occasional spells of night-blindness. This seemed to be the only symptom. His spells of night-blindness occurred periodically. As a rule, the patient had periods of from two to three days to seven to ten days in which the night-blindness was present, with free intervals between of from one to four weeks. There was no apparent cause for the exacerbations or remissions of symptoms. In addition, the onset of a period of night-blindness was usually slow, occupying from one to three days, usually the latter, whereas the attack usually subsided in one day. Peripheral vision seemed somewhat better to him than central vision.

A careful examination revealed the fact that in this case the manifest symptom of night-blindness was caused as a result of a gastro-intestinal disturbance interfering with either the normal digestion and assimilation of foodstuffs or their metabolic activity. An operation on the gastrocolic fistula corrected this defect and the night-blindness disappeared.

The case illustrates the care which must be observed in making a diagnosis and the need for occasionally searching beyond the immediate horizon of our own specialty to give our patients the attention they require.

C. C. K.

CORRESPONDENCE

A CASE OF EXOTROPIA*

Allow me to express my appreciation of Dr. Wyatt's article "A case of Exotropia." (American Journal of Optometry, January 1, 1934). He presented a clear statement of facts of an unsuccessful case. This is the kind of cases we can all learn something from, and indeed, my mind was so engrossed with this case that I could not get away from it and had to find some solution. I may be wrong in my solution, nevertheless, permit me to offer it for what it is worth.

In 1930 the patient was given the following prescription: O.U. +0.50 D. Cyl axis 90 ⌒ 3Δ base Out. It is evident that no exotropia was present then. Because, no matter how cursory and hasty an

[1]D. L. Wilbur and G. B. Eusterman. Nutritional Night-Blindness. Jour. A. M. A. Vol. 105, No. 5, pages 364-366.

*Received January 27, 1934.

examination may be, no examiner would give prism base-out in exotropia. So we draw our conclusion that the condition, then, was exophoria which, according to the prevailing conception, called for base-out treatment. But the patient was indifferent to orthoptic treatment he was given prism base-out in the correction.

The examiner has no definite data on this, so, our conclusion cannot be taken as contradictory to his.

In 1932 the same eyes showed decided exotropia. What took place is this: The P.D. is 70 and ½ mm. which is rather large. The additional six degree prism base-out increased the angular base or the P. D., and the resultant effect was; on one hand it over developed the volitional-end of the convergence by the constant effort for binocular vision and, on the other hand, it broke down the reflex end of the convergence by the large P. D.

Now, let us see how this tallies with the collected facts. "Deviation of O. D. varies under observation." "Exotropia becomes lessened when patient views close objects." "Patient is able, with mental effort, to converge to within 3 or 4 inches." All these seem to show that the exotropia is of a recent development. It also shows the, relatively, high development of the volitional convergence. "F. and L. test: Recognition of E with total of 32 prism base-out." "Fusion and depth perception was good when cards were set at position of esophoria 10 prism." These corroborate our view. Had the exotropia been of a long duration we would have not found the eyes in such a state. It is the existence of a pronounced exophoria, in the young eye, which has over developed the higher centers. It also indicates that the seat or the origin of the anomaly is not in the higher centers, and we must look for the same at the lower end of the organ.

"Exotropia has existed as long as he can remember." This is all well as far as the patient knows. There is no diplopia, and it has not come on suddenly, how should the patient know any different. "Is able, knowingly, to produce binocular single vision but when he does so vision is blurred." This is due to the "retinal slip." Since the binocular vision is produced with great effort the overlapping of the two images are imperfect, producing a blur.

"Habitual phoria—Esophoria 40 prism diopters." The evidence seem to show that there is some error about this phoria. An exotropia can be very readily be mistaken for an esophoria, as the patient's answers are identical in the two instances. There was no diplopia with this exotrope, and where there is no diplopia there is no phoria.

In exotropia both eyes turn to the right when the left is fixing, and both turn to the left when the right is fixing. In watching the movements of the eyes from behind the phorometer, from this position, the observer could see only one eye at the time, and when he watched one eye turning-in he could not see the other eye turning out. The 40 prism is, probably, the measure of the exotropia.

As to the difference in the findings, in the static skiametry, between monocular and binocular, we would say that it is purely optical, and it is an old story: The determination of the skiametric findings must be made close to the visual axis, otherwise, the obliquity of the lens and cornea will give a wrong finding. Changes in the alignment, during the test, must be expected. Particularly in a case where the binocular is held with great difficulty. Even under the most favorable conditions we are never certain of the proper alignment. Unless one is equipped with special instrumentations, static skiametry is a cursory test with approximate values only. For simplicity and accuracy the dynamic skiametry technic should be used, binocular or monocular as the occasion calls for.

For a clearer conception of the myological and neurological effects of this case we may take a common analogy with a machine. When in momentum, it calls for low motive power but high speed, the gears are set in high. When the occasion calls for high motive power, to do some strenuous work, the gears are shifted into low. The motor reaction of the lower visual centers are reflex. They are designed for instantaneous reaction or speed but of low power. In the normal, like the machine in momentum, its state is so conditioned that it calls for very little power but high speed, and the bulk of the work is performed by reflex. The motor reaction of the higher visual centers are designed for more strenuous work: Slow but of high power. Every malformation becomes an impediment to break down the low power reflex. The control is thus shifted to the higher centers, which, in the first stages, become more developed by exercise. A large P. D. is an impediment to convergence, and it must be classed as a malformation.

All our treatments may be divided into two classes; *corrections* and *training*. Anomalies in the lower end of the organ are malformations. They are not subject to training but are subject to corrections. Anomalies of the higher end of the organ are not subject to corrections but are subject to training: We correct a malformation of the cornea or ametropia, and we train acuity or fusion.

To trace the seat of the anomaly, the methods consist, first, the observation of all the facts which have a direct bearing on the case. Second, the analysis of the case. This is accomplished by the arrangement of the collected facts in the order in which they can show a consistent chain of evidence. The observer must view the eye as a living processes, with a multitude of factors. Each factor must be viewed from an angle which is best suited for it. The optical, the mechanical, the structural, the myological, the neurological, the physiological, the psychological, they all exist and our view must be broad enough to comprehend them all.

There are two ways of taking the P. D. of an exotrope. One way is to measure the distance between the pupils with the two eyes fixing at a common point by alternating; first one eye then the other. This gives the measure of the true P. D. The other way is to measure the P. D. while one eye is fixing and the other is deviated. This gives the apparent P. D., and the difference between the two measurements represents the

amount of the exotropia. In the quoted statement that the P. D. is 70 and ½ mm. we cannot say whether it is meant the true or apparent P. D.

To summarize our analysis of this case: The main facts are these:

(1) Patient is young.
(2) Decided exotropia of variable amounts.
(3) By mental effort he can overcome all of the exotropia and converge to a maximum of 3 or 4 inches.
(4) Stereoscopic fusion and depth perception by the maximum of mental effort, which is seen by the esophoric position of the steregrams.
(5) Ametropia is eliminated as a factor.
(6) Has been wearing prism base-out for two years.

We reason that the high development of the mental faculties must have received an undue amount of training. It points to the pre-existence of an exophoric stage, which trained these faculties. With the elimination of ametropia as a factor we trace the cause of the exophoria to an imbalance in the relative values between structural P. D. and the convergence reflex. The prism base-out completely upset the reflex arcs and the exophoria turned into exotropia. The treatment should have been prism base-in as a correction for the malformation.

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BOOK NOTICES

REPORT OF A JOINT DISCUSSION ON VISION. Published by the Physical and Optical Societies, I Lower Gardens, Exhibition Road, London S. W. 7, England. 327 pages, paper covers, 1933.

The discussion on Vision is a collection of papers presented before the Physical and Optical Societies at a meeting held at the Imperial College of Science. These papers were presented by leading scientists from different countries. Of the 28 papers, 25 are printed in English. Two in German and one in French. Ten papers were devoted to color vision and to experimental and theoretical considerations of this subject. Five papers are devoted to vision. Subjects discussed are problems of visual perception; interpretation of quantitative data in visual problems; new observations on the Weber-Fechner Law; a note on visual perception of depth; some problems of vision; investigations of the dark adaptation of the human eye and a contribution to a general theory of vision.

The seventeen papers mentioned deal more or less with the theoretical aspect related to vision and color vision. The rest of the papers are of greater interest to the optometrist because of the direct relationship they have to refraction, they deal with the equivalent adaptation levels in localized retinal areas; retinal action time; the physiological significance of the retinal synapse; the study of accommodation in the light of the newer research; visual acuity and retinal structure; visual acuity and the resolving-power of the eye; the mechanism of accommodation and the recession of the near point; some experimental observations on the properties of the receiving organs of the retina; subjective tests for astigmatism and refractive conditions for the peripheral field of vision.

The last two mentioned papers are of special importance. One of these papers is on astigmatism. The author describes a special technic of using a cobalt-lamp test with certain special filtered light discs. He makes use directly of the interval of Sterum by employing blue and red rays for the first and second focal lines. The other paper is entitled The Refractive Conditions for the Peripheral Field of Vision by Ferree and Rand of the Physiological Optics Research Laboratory at Johns Hopkins Medical School. The authors made a special study of the varying amount of refraction at different distances away from the center of the visual field. The results and conclusions of this experiment are very interesting. They found that when fixation was prolonged the hyperopia when great was decreased and when the eye was emmetropic it tended to become myopic. These changes were found to take place when the eye was fixed for distance or near. Also the changes were the same in the eyes examined with or without a cycloplegic. Ferree and Rand also report about the possibility to detect and determine the amount of refractive assymetry, whether the defect is in the refractive system and its position in relation to the visual axis.

It is to be hoped that at the future meetings of these societies more material of the type described in the last two papers will be presented.

J. I. K.

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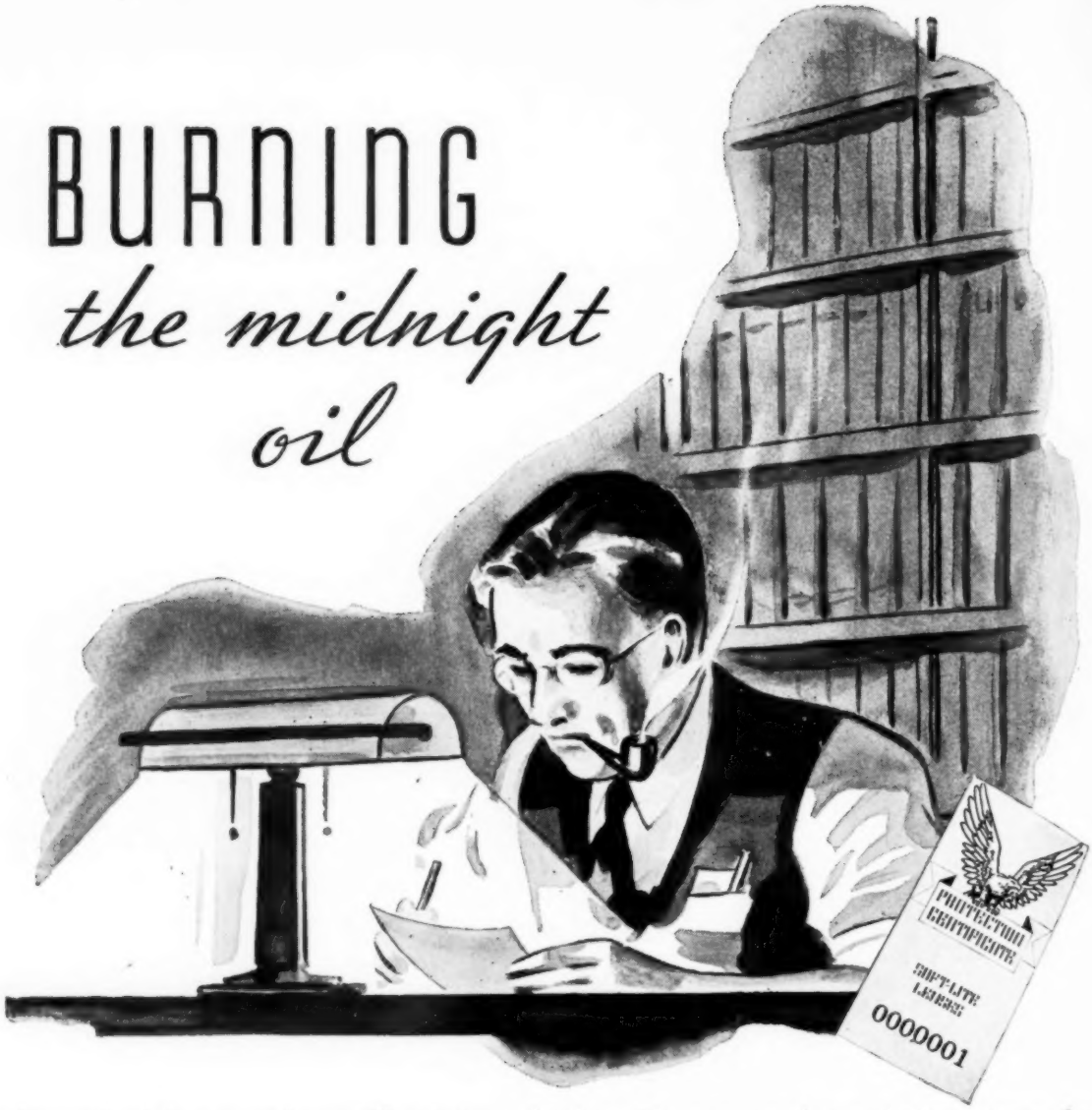

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Management and Circulation as required by the Act of Congress of August 24th, 1912, of the American Journal of Optometry, published monthly at Minneapolis, Minnesota, for April 1, 1934.

State of Minnesota, County of Hennepin—ss.

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THE EFFECTS OF EXOGENOUS TOXEMIA DIAGNOSED BY CHROMAGRAPHOLOGY*

Donald J. Mayer, Opt.D.

Riverside, California

A most evasive and baffling problem for the optometrist is to find normal chromagraphs when from the lowered ductions functional disturbances are suspected. Chromagraphs should not be considered normal and the patient should never be considered free from toxemia, or as having a tolerance for an existing toxemia unless the patient has eliminated the introduction of all toxicants to the system for a period of 24 to 48 hours. When this is done and only then, if the charts are near the expected normal can the case be considered toxic free, or as having tolerance to any existing toxemia.

An exogenous toxemia may completely cover an endogenous toxemia, so that, when the use of all stimulants is stopped the chromagraphs may show a focal infection; or without the stimulation the chromagraphs may reveal an existing abdominal toxemia, or the existence of systemic toxemia which is not localized and accompanies low blood pressure conditions.

The important factor is this, an exogenous toxemia may exactly balance, or neutralize an endogenous toxemia so that the later may seem to be rendered inactive.

This is often the problem confronting the optometrist, the balancing of the two types of toxemia gives a resultant chromagraph that may be near the expected normal and yet the existence of two types of toxemia are causing a great deal of ocular stress or discomfort and both must be eliminated.

To illustrate this type of case let us consider the following clinical data:

*Submitted for publication Feb. 13, 1934. Paper read before the Beta Chapter of Phi Sigma Epsilon Feb., 1934.

Patient Mr. C, age 46, July 7, 1930. Mr. C complained of a frontal headache coming on in the afternoon, very nervous, insomnia and a general lassitude more severe of late. Patient had history of continual low blood pressure over a period of many years. Examination revealed all ductions very low. A definite need of glare protection in lenses. Blood pressure of 100 mm. systolic taken several times and showing no variance. Ophthalmoscopy showed a condition of venous stasis, but no other indication of pathology. Trans-illumination disclosed normal sinuses, throat and teeth appeared normal.

My skiascopic and subjective findings appeared to be very much like the prescription he was wearing. The change in my prescription not being great I will not cover that part of the work.

Chromagraphic examination disclosed the presence of exogenous toxemia. The blue fields were near the expected norm, nasalward 48 degrees, temporalward 38 degrees, upward 26 degrees and downward about 30 degrees. The green fields were of the expected size of the red fields being nasalward 32 degrees, temporalward 28 degrees, upward 22 degrees, and downward about 23 or 24 degrees. The red fields were very nearly covered by the green fields, a patch of red appeared in two or three places on the outside of the green fields.

A set of chromagraphs were made eight hours later and both charts (right and left eye charts) were very much the same as the charts made in the early morning. A third set of chromagraphs, made a day later, showed the green fields enlarged even more, for at this time they overlapped the blue fields in the vertical meridians, but was explained by the introduction of several drinks of gin into a system already over stimulated.

Stimulants were prohibited for 24 hours and chromagraphs again made. The chromagraph of the right eye disclosed a normal blue field, a normal green field and a red field following exactly the contour of the green field, but about 5 degrees larger all around although much too small. The chart of the left eye showed a normal blue field with a small red field and a small green field. This last set of charts plainly indicated a systemic toxemia bordering a focal infection.

Medical examination disclosed the presence of an intestinal disturbance; the aftermath of stomach ulcers which seemingly had responded very well to treatment given many years before the patient had any eye trouble. The patient was put on a definite program of treatment and the physician reported the case well under control.

Further charting of the color fields revealed a tolerance of ten cigarettes and one cup of coffee used daily. The physician to whom I referred the case excluded the use of alcohol.

These two types of toxemia being reduced to tolerance, as shown by the chromagraphs, the patient immediately reported a great improvement in his general health and the condition of his eyes. A recent check examination indicated a normal increase in the bifocal addition. The patient has no distressing ocular symptoms as he had in 1930.

My colleague, Dr. Keith Walker, had a similar, or parallel case to this one. Patient Mrs. W., age 59. Lenses prescribed 18 months previously. Symptoms: Headaches, occipital and frontal, dizziness, and extreme tiredness of eyes after near work. Blurring and fading of print after reading a few minutes.

Re-examination showed no change of lenses, but ductions were abnormal with low recovery points.

Chromagraphs made at 9 a.m. revealed blue and red fields small, all fields inside the 30° circle and fields interlaced, green overlapping red in nearly all meridians and greatly enlarged, showing exogenous toxemia. Patient said she used from 8 to 11 cups tea daily.

Recharted again at 4:30 p.m. same day, but without use of the stimulant tea. All fields smaller, the blue and red fields interlaced badly, but the green was inside of the red field. These chromagraphs made in the late afternoon indicated an endogenous toxemia of abdominal origin.

The patient was advised to have a urinalysis made which showed the presence of much indican which in itself shows the presence of intestinal stasis, also inflammation of the urinary tracts.

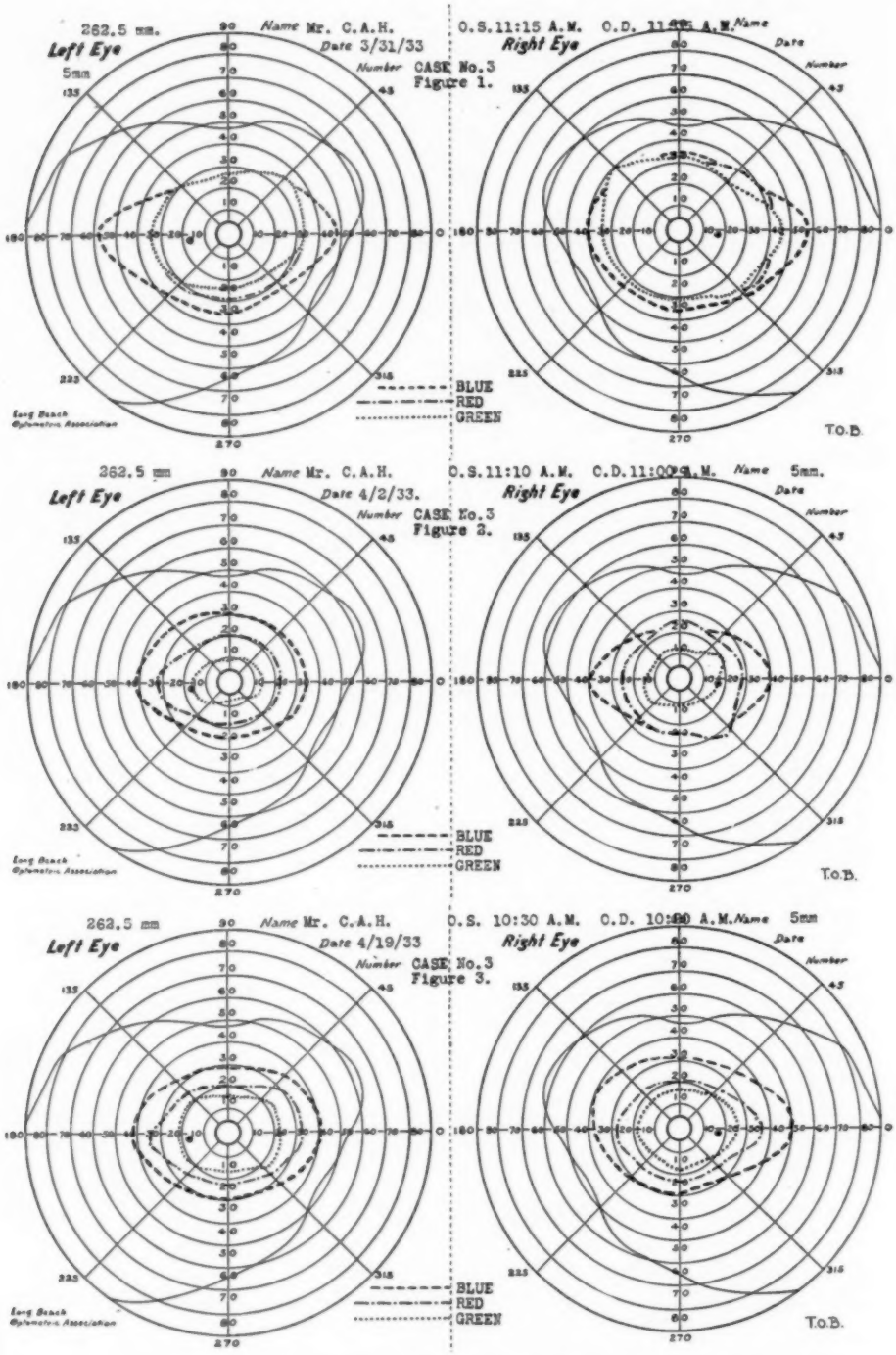
With the cooperation of the patient's physician an elimination fast was advised. This was a fruit juice fast of four days after which the chromagraphs were again made. These graphs showed the blue fields 45° and 25° in the horizontal and some interlacing with the red fields, with the green overlapping the red fields and some of the blue fields, indicating that the toxic condition was being relieved and patient was returning to a normal condition, for the fields were going back through the stimulative stage to normalcy.

The fast was continued two days more and chromagraphs made. The graphs showed the green and red fields normal, but the blue fields a little small. The fast was ended and diet corrected.

Chromagraphs taken two weeks later were found to be normal for both eyes. Patient reported all eye symptoms gone and feeling better physically than she had for ten years previously.

Although the optometrist may be positive of the presence of endogenous toxemia the patient may have built a tolerance to the existing toxemia, or his resistance may be so high that the toxemia is neutralized, or rendered inactive as fast as it forms.

Recently while making an examination I felt assured from my previous work that the chromagraphs would reveal focal infection; to my surprise the charts showed exogenous toxemia and the elimination of the stimulants (toxic agents) gave charts that were fairly normal, just bordering focal infection. This evidence disclosed the following facts: the patient was resisting the incursion of focal infection which would indicate the suspected sources had become imbued very slowly and tolerance, or resistance, had increased in proportion. The exogenous toxemia was not in the least being tolerated and was causing a great deal of trouble manifested by ocular symptoms.



Dr Donald J.Mayer. Three Chromagraph charts showing the size of the color fields on March 31st (Fig.1): April 2nd (Fig.2) and April 19th (Fig.3)

Although at the present time the patient is resisting the incursion of endogenous toxemia of focal origin, in six months, or a year his tolerance may be so altered that at that time the chromagraphs would reveal focal infection.

The discussion of this case follows:

Patient Mr. C. A. H., age 57. Mr. H. was referred to me by a very competent dentist. His main symptoms were trouble in reading, an inability to see clearly at near followed by a muscular tiredness. He was aware of a sinus disturbance mostly frontal, but sometimes the maxillary sinuses bothered.

Trans-illumination showed the right frontal sinus to be slightly cloudy, all other sinuses clear. The entire mouth appeared to be affected by pyorrhea and the throat showed a chronic irritation. Blood pressure normal and ophthalmoscopic evidence negative.

Examination of the ocular muscles revealed a low positive fusion reserve with a break point of 8 prism dioptres base-out, and a reversion of 8 prism dioptres base-in, subsequent tests were even lower. The adduction was extremely low, while all other muscle tests were quite normal.

The refraction was not difficult and his prescription was made in bifocal form. The prescription called for a normal increase in power for the major spherical correction and an increase in power of the segments, also a slight cylindrical correction at 180 degrees.

The first and second set of chromagraphs made within 24 hours were practically the same, the difference not being great enough to note in this case review.

The accompanying graphs, Mr. C. A. H., Fig. 1, show the color fields greatly enlarged with the green field overlapping the red and also the blue fields. At the time these chromagraphs were made the patient was drinking three and a half to four cups of strong coffee daily, smoking one pack of cigarettes daily and smoking one can of pipe tobacco in every three or four days.

The patient was asked to refrain from the use of all stimulants for a period of 30 hours. This was done with the exception of smoking one cigarette shortly before the second set of chromagraphs (Mr. C. A. H., Fig. 2) were made. The chromagraphs of the right eye show the red fields overlapping the blue field in the vertical meridian. This is due to the reversion of the fields although if several chromagraphs were made revealing similar results the graphs would indicate faulty elimination. The chromagraph of the left eye shows the green field bordering focal infection. The red and blue fields of the left eye are near normal.

The patient was then advised to reduce the amount of coffee by half and to reduce the smoking by more than half. The patient being a writer and a former army officer, felt the need of both tobacco and coffee and wished to establish a tolerance to these stimulants in the shortest possible time.

Sixteen days later the chromagraphs were made (Mr. C. A. H., Fig. 3) and were found normal. As was before stated the presence of focal infection was practically established by the extra ocular tests and the case history. The patient's mouth revealed the presence of pyorrhea and the patient was aware of some sinus trouble which was substantiated by the fact that the right frontal sinus was cloudy. The patient resists the incursion of focal infection and tolerance to the stimulants he is using has been established.

Mr. H. states that he feels that his health is very much improved and his eyes feel a great deal better. Orthoptic treatment has been instituted to relax the ocular muscles and correct the imbalance, and Mr. H. has been advised to have a complete oral examination with full mouth X-Ray. Clinical evidence indictes that the dental trouble is the primary source of infection and the sinus condition is secondary in cases of this kind. The chronic throat irritation is found in all users of excessive amounts of tobacco and will now improve.

The dental disturbances would have all been taken care of before referring the patient to me for ocular attention other than the chromagraphs had not Mr. H. so felt the need of new glasses. This dental work will be done in the near future.

As an example of perfect tolerance I will cite this case: Patient Mr. W. E. H., age 48. On June 24, 1930, Mr. H. came in the office complaining of his eyes and he made the statement, "I believe I smoke too much, tell me how much to cut it down." Complete ocular examination was made and the chromagraphs were found to be near the expected norm. Upon questioning the patient, it was found that the following stimulants were used daily, nine to twelve cigars, six to ten glasses of coca cola and three cups of black coffee. Mr. H. was advised to refrain from the use of all stimulants for 36 hours and at the end of that time the chromagraphs were made and found to be perfectly normal. The charts were made morning, noon, and night for several days, but were always normal. Mr. H. had built resistance to these stimulants for a period of 30 years and they were not causing an accumulation of toxemia, but were being tolerated.

The ocular condition required a prescription in bifocal form and some orthoptic training for relaxation. The patient was told that while his tolerance was very high that if anything lowered his resistance then an exogenous toxemia would at that time be shown to be present and by our color field charting we could determine the stimulants causing trouble and also determine the amount of reduction necessary to again establish tolerance.

At the end of two and a half years this patient reported no ocular trouble and the chromagraphs were still normal.

Coffee drinkers wishing to free themselves of the ill effects of over stimulation from coffee often use Sanka coffee with benefit, but the person not used to drinking much coffee sometimes receives as much stimulation from these several brands of so-called health coffee as if he

were using some known brand of strong coffee. This is shown by the following case:

Rev. James E. B. This patient, a minister, called to have his eyes examined and complained of his eyes stinging and a great deal of strain at near. After his daily study he was always very nervous and tired which disturbed him a great deal.

The patient's blood pressure was a little high, but the rest of the examination was not unusual at all until the chromagraphs were made. These showed the exogenous type of toxemia, or great stimulation. The patient said he was using no stimulant, but after careful questioning I found he was using three cups of Sanka coffee daily (he did not consider this coffee stimulating and used it because he liked a hot drink). The first set of chromagraphs (case 5, Fig. 1) show the effects of the stimulation. The green fields have spread out as a drop of ink spreads on a blotter until these green fields have overlapped the red fields. This enlargement of the green fields show stimulation, or exogenous toxemia introduced to the body by improper hygienic habits which in this case was the effect of the three cups of Sanka coffee.

The Rev. Mr. Burkhart was advised to do without, or exclude the use of the coffee for four days. Four days later the chromagraphs were normal (case 5, Fig. 2). This case plainly reveals the stimulating effect of health coffee on a patient not used to stimulation.

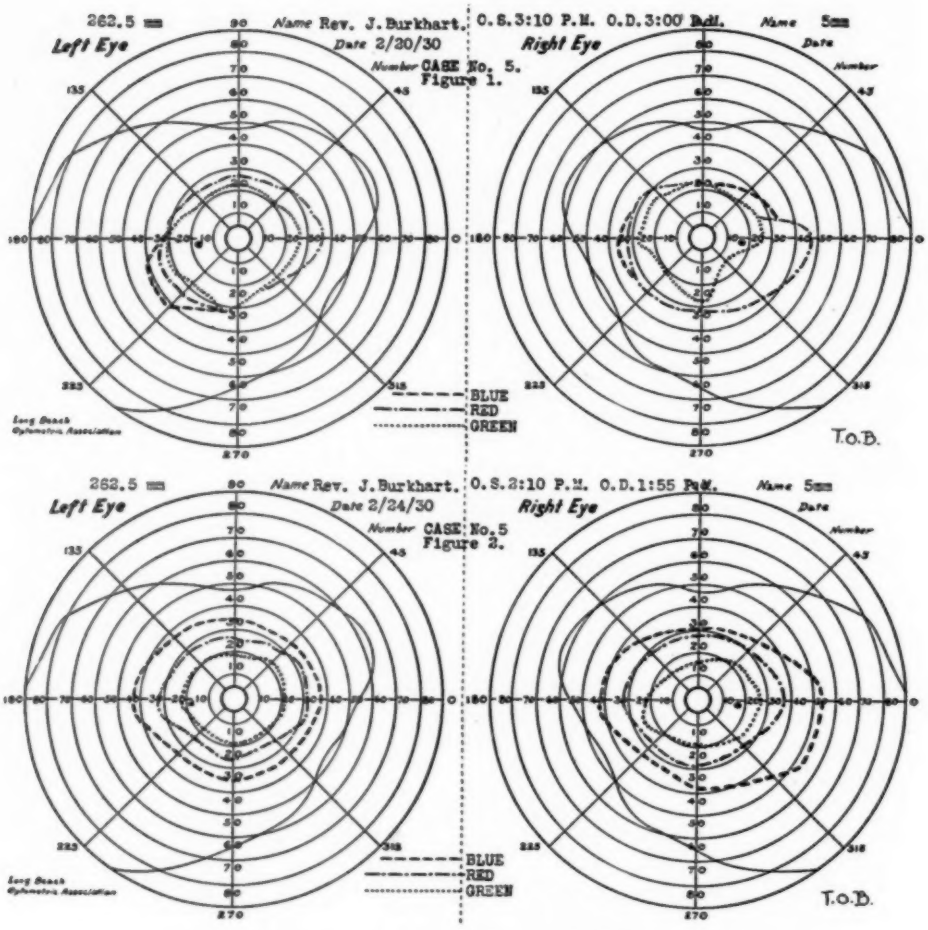
An interesting case showing how the patient's tolerance is established is that of Mrs. P. B. as follows:

Mrs. P. B., age 54, came in for examination December 31, 1932. Her chief complaint was floating spots in the visual field (Muscae Volitantes) which were quite constant, inability to wear bifocals with comfort, and severe photophobia.

Mrs. B. had had her eyes examined and glasses prescribed three times in the two years previous to coming to me. No help, or ocular comfort had been given her.

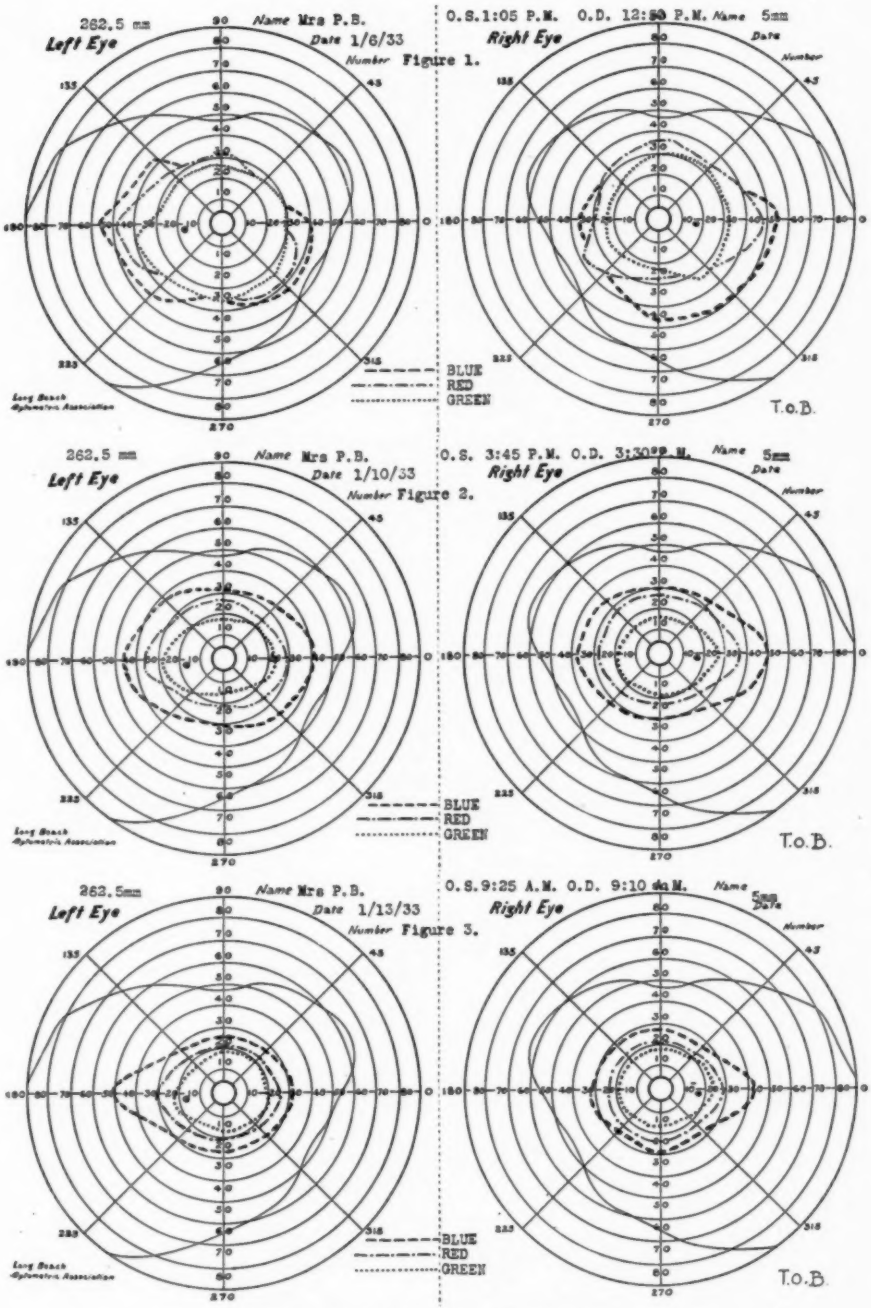
The only unusual, or abnormal findings in the examination were a systolic blood pressure of 165 mm. and a faulty myological condition which revealed by several tests, 4 prism dioptres of exophoria at infinity with 18 prism dioptres of physiologic exophoria at near, convergence (adduction) at infinity 21 prism dioptres with recovery at zero, or 2 prism dioptres base-in, and a positive fusion reserve at near of 32 prism dioptres with recovery at zero, abductions were near the expected normal. 1½ prism dioptres of right hyperphoria at near with 1 prism dioptre of right hyperphoria at infinity.

The chromagraphic examination revealed exogenous toxemia, or a severe type of stimulation (Mrs. P. B., Fig. 1). The patient was drinking six, or seven cups of coffee daily, smoking an average of six cigarettes, and drinking two cups of tea daily. Mrs. B. was instructed to do without all stimulation for 36 hours, at the end of which time the chromagraphs were perfectly normal and showed an absence of toxemia (Mrs. P. B., Fig. 2).



Dr Donald J. Mayer. Two chromagraph charts showing the size of the color fields, first on Feb. 30th (Fig. 1) while patient was using three cups of Sanka Coffee daily and second, on Feb. 24th (Fig. 2) the normal fields.

I then instructed Mrs. B. to reduce the amount of coffee she was drinking to two cups and to use the same amount of cigarettes and tea that she was in the habit of using, and in three days another set of chromagraphs would be made. This third set of chromagraphs (Mrs. P. B., Fig. 3) while smaller than the ones made after all stimulation was excluded showed tolerance to stimulants in use. Had not this third set of chromagraphs shown tolerance then the cigarettes would have been excluded and graphs made. If tolerance had not then been revealed the patient would have been instructed to use coffee and cigarettes, but exclude the tea and chromagraphs then made. In this way we can find the exact amount of stimulant the patient can use and as long as the patient



Dr Donald J.Mayer. Three chromagraph charts showing,first, the size of the color fields on Jan.6th.(Fig.1). This is the result of an exogenous toxemia stimulation. The Patient being in the habit of using an average of 6 to 7 cups of coffee, 6 cigarettes and 2 cups of tea daily. Second, the color fields on Jan.10 th. (Fig.2) taken after no stimulation for 36 hours, and third, the color fields on Jan 13th,(Fig.3),the patient having resumed the use of stimulations,the chart being normal.

keeps within those limits his, or her system is not affected by exogenous toxins.

I prescribed bifocals for Mrs. B. and gave her orthoptic treatment, the course of treatment extending over a period of two months. The program of optometric hygiene relative to chromagraphology was carefully followed and ten weeks later a re-examination of her eyes revealed a normal muscle balance, no hyperphoria, normal blood pressure and Mrs. B. had none of the disturbing symptoms she first complained of.

Re-examination six months after patient was released showed the same conditions and tolerance, and Mrs. B. is a happy and satisfied patient.

Endogenous toxemias (focii of infection, abdominal toxemia, etc.) outnumber the exogenous toxemias (toxicants introduced to the system) about ten to one. Clinical evidence proves that approximately 98 per cent of all the patients coming to you for optometric care and services are affected by toxemia, either exogenous, or endogenous. Therefore, perhaps eight or nine patients out of every 98 that you care for are affected by one or more toxic agents which the changing of their hygienic program would eliminate.

Of course all nine of these cases will not be in that stimulative state that makes their recognition easy, but by careful chromagraphic investigation and follow through work you will be able to advise, or instruct these patients so that they will have ocular comfort and relief they otherwise would never have.

The skiascopic examination and the entire myologic examination, as well as all of your advocated diagnostic procedures presume the eyes to be toxic free, and unless the case is free from toxemia your entire diagnosis is incorrect because of faulty and untrue findings.

The optometrist practicing diagnostic and corrective optometry can easily be quipped to do good work in chromagraphology. One can as well do without the ophthalmometric, or skiascopic examination as without the chromagraphic examination.

In the past many of these cases were classified as "grief" cases and it was thought that no relief could be given these patients. There are many patients that are having a fair degree of ocular comfort and many patients that are simply "getting by," but are not overly pleased with your optometric care and glasses, that would have added comfort and usually complete relief if a program of optometric hygiene was instituted to eliminate exogenic toxicants after recognition of exogenous toxemia by chromagraphology.

Recently I observed a case in which small doses of castor oil was causing an exogenous toxemia that greatly affected the balance of the ocular muscles. It is not unusual to find perfect tolerance of one patient smoking ten cigars daily while for another patient in seeming better health and a finer physique one glass of ice tea taken daily causes the same stimulative effect that several drinks of alcohol does for the person taking alcohol for its stimulative effect and making a habit of it.

Conclusion

1. All chromagraphs must be made under conditions of control. The patient must implicitly follow the instructions of the optometrist regarding all advice on optometric hygiene.

The arc of the perimeter must be evenly illuminated by a constant and unvarying source. The perimetry room must have approximately the same amount of illumination at all times.

2. As stated in a previous paper,[1] your diagnosis can be made only from a series of chromagraphs made at different times (different hours) over a period of 24 to 48 hours.

3. Color vision is taken in all cases before the chromagraphs are made. Defects in color vision influence the chromagraphs, but little for even the patient that is color blind partially, or totally can differentiate the fundamental colors, by the intensity of shade or hue.

It is surprising the number of men that are apparently partially color blind due to a poorly developed color sense. This is a lack of education in color distinction, or discrimination of co'or, and not at all color blindness.

Chromagraphic data is being secured through clinical investigation of patients showing the various type and degree of color blindness. The lack of clinical case evidence makes it impossible to publish the interesting things that have made their appearance to date.

4. Optometrists of today doing diagnostic and corrective work are scientific men. Their work is systematic and exacting. Science says the first word on everything and the last word on nothing. The more that is known of any scientific subject the less it is condemned.

I earnestly plead that optometrists not offer adverse criticism of color field charting until they chart and follow through at least six hundred cases, then they will have valuable evidence to offer the profession and their criticism will be constructive.

DR. DONALD J. MAYER
215 CITIZENS BANK BUILDING
RIVERSIDE, CALIF.

[1] Donald Mayer. Focal Infection Diagnosed by Chromagraphology. Amer. Jour. of Optom. Vol. 10, No. 1, pp. 5-21. 1933.

METASTATIC CALCIFICATION-HYPERPARATHYROIDISM*

Russell E. Simpson, O.D., F.C.O.R.I.

Pasadena, Calif.

Calcification, the process by which organic tissue becomes hardened by the deposit of calcium within it.

In the last ten years increased attention has been directed to the study of calcium metabolism. It is believed that normally calcium salts are deposited in the formation of bone. Investigations into and the knowledge of calcium deficiency (rickets, etc.) are numerous and enlightening but the knowledge of calcium excess in humans is limited.

While it is recognized that calcium is an essential element of the body, opinion is quite at variance regarding the amount necessary in our diets. There is also considerable variance in what is considered a normal blood calcium content. Blood serum has become recognized as probably the most reliable for blood calcium tests. Cantarow[3], page 39, in tests on 68 normal adults arrived at the conclusion that a variation of from 9.2 to 11 mg. per 100 cc. was normal and these figures are becoming more generally accepted.

The statement can probably be made without fear of contradiction that calcium salts are absorbed from the upper intestine. Cantarow[3] states, "the absorption of calcium is governed chiefly by three factors: 1. The hydrogen-ion concentration within the intestine; 2. The relative proportion of other substances in the diet; 3. Vitamin D." Further, "experimental work has shown that calcium is absorbed in the small intestine. Solubility is, of course, essential to absorption. Certain substances influence the absorption of calcium apart from any influence upon the intraintestinal hydrogen-ion concentration. Chief among these are fats and inorganic constituents of the diet. It was maintained by some that the addition of fat to the diet greatly increased the absorption of calcium; others believed that absorption was diminished by fats. At the present time it appears safe to assume that, apart from the effect produced by Vitamin D, an excess of fat tends to inhibit the absorption of calcium. Vitamin D, the "antirachitic factor" the "calcifying factor" is a substance essential to normal calcium metabolism. In contradistinction to

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the other recognized vitamins it has an extremely limited distribution in foods. The only substances in which it exists in amounts sufficient to render them of practical importance from this viewpoint are egg-yolk and halibut- and cod-liver oils and to a much lesser degree, the cream of cows' milk."

Calcium excretion[3]. "In investigations of calcium excretion, difficulties are encountered similar to those met with in studying calcium absorption. The recent work of Bergeim, however, has demonstrated quite conclusively that calcium is excreted by the epithelium of the large intestine as well as by the kidneys. The relative amounts excreted through these two channels are difficult to estimate since the fecal calcium represents the portion which has been unabsorbed and the portion which has been absorbed in the small intestine and excreted in the large bowl. In the normal adult the supply, absorption and utilization of calcium being adequate, the total daily output is approximately equal to the intake, the storage of calcium being practically negligible."

The relationship between thyroid secretion and mineral metabolism has attracted considerable attention. The extraction by Collip of a potent hormone of the parathyroid glands has provided a means for accurately studying the role of these glands in calcium metabolism.

Barr[1] states, "during the last few years our knowledge of pathological calcification has been greatly extended by studies of calcium deposit in normal ossification and in rickets, and by physiochemical investigations of the state of calcium in the tissues and body fluids. Of special interest is the relationship of calcification to disturbances in parathyroid function and to overdosage with irradiated ergosterol."

In 1931[6] the writer presented to the California Optometric Research Institute his findings in recognizing from the eye intestinal auto-intoxication and diatetic disturbances. It was recognized as presented, that further developments probably could be made. Two of the four characteristics noted in those findings were a chronic inflammation and fatty, cheesy, calcareous deposits in the conjunctiva. It has been noted that both these conditions may be present in cases negative for intestinal auto-intoxication. We now believe calcium disturbances may be the answer in some of these cases. However, it is very evident there is some connection between the two-auto-intoxication and calcium disturbances. Two cases of calcium deficiency have been noted by the writer and the one case of calcium excess later to be described.

Renal disease seems to be a very frequent accompaniment of pathological calcification. Cantarow[3] states, "in some cases of advanced nephritis with uremia and phosphate retention the serum calcium may be increased. This is difficult to explain, etc. Defective elimination may be an important determining factor in this connection. In these cases of nephritis with hypercalcemia metastatic calcification may be present."

Klotz[2] advanced the theory that while fat and fatty acids are not involved in calcification of normal bone, believed that calcareous

degeneration may be preceded or accompanied by deposits of soapy material. He believed that soap exists in areas of chronic inflammation before lime is deposited, following that, calcium salts are attracted and as the soap and fats disappear they are replaced by calcium. Hofmeister[4] reporting on work of Tanaka, believed that fatty tissues contacting calcium salts become calcified. However, Hofmeister points out that in experiments in which large amounts of calcium are injected, distant calcium deposits may be found in 24 hours, an interval presumably too short to provide for the preliminary deposition of fat and the formation of fatty acids.

For purposes of discussion we will consider the following forms of calcification; hypercalcemia, metastatic calcification, hyperparathyroidism.

Hypercalcemia: an excess of calcium in the blood.

Metastatic calcification: the process by which organic tissue becomes hardened by a deposit of calcium salts in its tissue resulting from an excess of blood calcium salts, frequently destructive bone lesions being found as an accompaniment.

Virchow[5] proposed in 1855 according to Barr[1] that destructive bone lesions could cause an excess of calcium salts in the blood stream, which if not promptly excreted by the kidneys, might be deposited in soft tissues where there had been no previous tissue damage.

Records are very rare of this type of case in human pathology, only 71 cases being recorded, since and including Virchow's original description of the disease, when he reported five cases of destructive bone lesions with nephritis, and one case of nephritis without bone lesions. Since 1915 only 10 cases are reported in literature. The writer hopes and believes, that from the examinations as conducted by Optometric Eye Specialists many cases of this disease can be recognized prior to the death of the patient.

Barr[1] states, "In all of the conditions which have been carefully studied, metastatic calcification has been accompanied by hypercalcemia, by increased urinary excretion of calcium and, in several cases by large kidney stones—phenomena which may possibly explain its not infrequent association with renal disease. In the presence of hypercalcemia a serious kidney lesion might be the additional factor essential for precipitation in tissues. Recently, we have observed, with Dr. Howard McCordock, of the Department of Pathology, a case of hypertensive nephritis in which there were extensive deposits of calcium in the alveolar walls of the lung and in a thrombus of the right auricular appendage. There was also a necrosis of cardias muscle, some bundles of which were infiltrated or actually replaced by calcium. In this case no bone lesions were found and a disturbance of calcium metabolism was not suspected during the life of the patient."

Hyperparathyroidism

There has been in the past considerable difference of opinion regarding the affect of parathyroid function on calcium excretion. Cantarow states, "most of the evidence produced in recent years indicates that the administration of parathyroid extract results in an increased elimination of calcium. Greenwald and Gross found that the elimination of calcium was diminished after parathyroidectomy and that the administration of parathyroid extract to dogs was followed by an increase in the amount excreted. These authors conclude that since no calcium was supplied the excess must have been abstracted from the bones." Collip has shown that by means of frequently repeated injections of the hormone a state of marked hypercalcemia may be produced rapidly and maintained for several hours with a characteristic train of associated metabolic phenomena and serious symptoms terminating fatally. It has been demonstrated that the bones are the storehouse of available calcium and that the increase in circulating and excreted calcium is derived from this source in the absence of adequate supply attending the introduction of an excess of parathyroid hormone."

"Experimental work by Collip demonstrated that a maintained serum calcium of 20 mg. per 100 cc. terminated fatally with preceding uncompensated acidosis."

Cantarow states, "widespread calcific deposits have occurred in various organs. Peneke reported calcification in the left heart, the smaller arteries, the thyroid, kidneys, etc., and in the parathyroid tumor itself, the patient dying of renal failure."

Cantarow under the heading Muscular Hypotonia states, "There is frequently a marked reduction in nerve and muscle excitability as evidenced by decreased response to electrical (galvanic) stimulation. Many patients suffering with this disorder complain of muscle weakness." Optometric Eye Specialists accustomed to testing the neuromuscular tonicity will evaluate this statement.

The following case is presented as the 72nd case ever reported of metastatic calcification and the first in which there was an involvement of eye tissue found and reported. It is one of a very few in which no destructive bone lesions could be demonstrated and also has this distinction that it does not demonstrate any renal involvement.

September, 1933, Mr. G. age 31, reported for examination, requesting glasses.

Symptoms: Gritty, sandy condition of lids, intolerance of light.

History: Had been under care of one optometric eye specialist and two medical eye specialists. Lids had been treated four months 3 times a week. Had O. U. +0.50 D. Sph. ⌒ +0.25 D.Cyl. axis 90 from one specialist who had removed his tonsils. Another had prescribed identically the same prescription for glasses as the first. Appendectomy had been performed. None of these measures had given relief.

Examination: O. U. +0.50 D. Sph. ⊂ +0.25 D.Cyl. axis 90 vision uncorrected 20/20 O.U.

External examination: Pupillary reflexes normal, cornea normal.

Lids: Chronic, uniform inflammation with numerous calcareous deposits.

Color fields: Normal for relationship and size.

Neuromuscular tonicity for close: Positive 13-10, Negative 16-12, constant on three examinations. A fourth made January, 1934 gave Positive 16-12, Negative 14-12.

Fundus: Two definite, slightly elevated, round creamy white elevations, one of the size of a pin head the other half that size were seen. They were definitely unlike the patches of degeneration found innepritis, etc. No indistinct area surrounded them.

Further questioning developed that patient was tired most of the time. That he considered his energy was considerably less than he would expect for his age. His teeth are soft and numerous cavities have existed.

Metastatic Calcification was seen as a possibility. Urinalysis and blood serum were ordered. Urinalysis report showed calcium crystals. Blood serum was 14.5 mg. per 100 cc.

On Nov. 7th this patient was referred to Scripps Metabolic Clinic at La Jolla, California, for general examination, Francis M. Smith, M.D. being the Clinician in charge. The following is their partial report:

"Attendance at Clinic 10 days under complete calcium balance.

Serum calcium varied between 11.3 mg. to 15 mg. per 100 cc., Phosphorous from 4 to 4.8 mg. per 100 cc. Urine calcium approximately two times the normal.

No X-ray evidence of loss of calcium from the bones could be demonstrated and no metastatic calcification other than the involvement of the eye as previously found could be discovered.

Tentatively it is assumed an exploratory operation on the neck will be in order to discover a tumor or over active parathyroid glands, the case seemingly being one of hyperparathyroidism."

If, as in this case reported of hyperparathyroidism, which were it not for the recognition from the eye might have gone on to eventual painful fatality, we can discover other conditions which today are not recognized from the eye, our value to our communities will be enhanced. Apparently we have not as yet realized to what extent the visual apparatus can reveal to us systemic and organic conditions of the human body. The importance of early remedial measures in curing bodily ailments cannot be overestimated.

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BIBLIOGRAPHY

[1] David Preswick Barr, Department of Medicine, Washington University, St. Louis, Mo. "Pathological Calcification," Physiological Reviews, October, 1932.

[2] Klotz, O., quoted by Barr. Studies upon calcareous degeneration. The process of pathological calcification. Journ. Exp. Med., 1905, vii, 633.

[3] Abraham Cantarow, M.D. Calcium Metabolism and Calcium Therapy, Second edition, Lea and Febiger.

[4] Hofmeister, F., quoted by Barr. Uber Ablagerung und Resorption von Kalksalzen in den Geweben. Ergebn. Physiol., 1910, x, 429.

[5] Virchow, R., Kalkmetastasen. Virchow's Arch., 1855, viii, 103.

[6] Russell E. Simpson, American Journal of Optometry, Jan., 1932. The Early Recognition of Auto-intoxication and Dietetic Disturbances Through the Conjunctiva of the Eye

SUGGESTIONS FOR PRESCRIBING ABSORPTION LENSES*

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A great deal has been written relative to the therapeutic use of absorption lenses in optometric practice. Nevertheless there still exists in the minds of many optometrists a question as to just when and in what manner absorption lenses should be used. Obviously the question is closely allied with that of photophobia. The prescription for lenses, particularly the one correcting or reducing excessive convergence is, in the author's opinion, a more potent factor in the correction of photophobia than any sort of absorption lens. This excludes, of course, such unusual working conditions as prevail in the tropics, in arctic snowfields, near blast-furnaces, acetylene and electric torches, etc. Albinos also present peculiar difficulties. We will, however, ignore these special cases for the moment, and consider the photophobe of "normal," or "average" *present day* environment, normal pigmentation, but having a refractive error, and, usually, a muscle imbalance as well, this imbalance frequently tending to esophoria at a distance, low physiologic exophoria, and all cases in which convergence and accommodation are closely associated. Cases having a loose hook up between convergence and accommodation are considered later in regard to photophobia.

Certain evidence indicates that excessive stimulation of the eyes and blood stream to strong white light lowers the systolic blood pressure appreciably. This appears to be particularly true of normal sunlight, and the effect is intensified with the intensity of light and duration of exposure.[1]

Upon investigation, the author has found that patients having low systolic blood pressure are made decidedly uncomfortable when exposed to normal sunlight, and it is a recognized fact that if the uncovered head be exposed to intense sunlight that the blood pressure will be reduced remarkably.

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[1] J. O. Baxter, Sr., Opt.D., and J. R. Latham, M.D., of New Bern, North Carolina, performed original experiments in this field several years ago, their results appearing in this JOURNAL at that time. The Effects of Absorption Glasses on the Nervous System, with a few notes on the changes effected in Patient's Blood Pressure by the use of these Glasses. J. O. Baxter, Sr., Am. Jour. of Optom. Vol 6., No. 1., pp. 38-41. 1929.

We would expect photophobia, under these circumstances, from a patient having a low systolic pressure, once in possession of the facts concerning such cases. Such a case, the author has found, is made materially more comfortable by wearing an actinic lens such as Crookes, Cruxite, Viopake, and Novial. Continued experiments have failed to show that any appreciable results are to be obtained from non-actinic absorption lenses in a photophobe of low systolic pressure, so that we must conclude that the further lowering of the pressure is due to some quality of light which is absorbed by an actinic lens. If this be other than ultra violet rays, what might it be?

Patients with high systolic pressure, on the other hand, will nearly always inform you that they are more comfortable out-of-doors, feel better on bright days, and that darkness "depresses" them. Such a patient can never wear an actinic lens, whether he be photophobic or not. If photophobia be present in this sort of case, it should be determined whether or not a refractive error or some muscular imbalance is not the root of the trouble. If it is not corrected by proper lenses, we should investigate further, using tinted lenses only when convinced that there is no hidden cause for the ailment.

As has been implied, any muscular imbalance that involved the iris positively (excessive third nerve stimulation) would cause a contraction of this organ. Might not this very contraction cause the same sensation of photophobia as is caused by excessive light stimulation? Most of us have noticed that photophobia would be one of the symptoms exhibited by such a patient, and that it would be relieved when the proper correction was worn. It seems fairly conclusive that such photophobia is just another phase of asthenopia, and should be so regarded.

A different type of case, in which there is photophobia present in connection with a loose association between accommodation and convergence extends our investigation, and makes all photophobes subjects of careful thought, is the following: Patient G. Age 21. This patient required by both dynamic skiametry (Tait), static skiametry and subjective tests the following correction: O.D.—0.50 D.Cyl. axis 90. O.S.—0.37 D.Cyl. axis 90. Without this correction there was 4Δ of exophoria at 6 meters and 14Δ of exophoria at 33 cm. With the correction this is ½Δ of exophoria at 6 meters and 5Δ of the exophoria at 33 cm. The patient complained of extreme photophobia which interferred with his work (civil engineering). The correction indicated, in which crown glass was used, gave him complete relief from his photophobia. The cause is obvious: his pupils were dilated when his myopia was uncorrected, allowing an undue amount of light to impinge upon the retina. Tinted lenses, of any sort, would be superfluous in a case of this sort.

Thus we find that in two entirely different case types that we are confronted with the same phenomena: photophobia. In the one case (excessive convergence-accommodation) it is due not so much to the light itself as to the continual contraction of the iris, while in the other

case (loose association between convergence and accommodation), we find the photophobia not to be reflex in origin, but primary in kind, the dilated pupils actually allowing excessive light to enter the eyes.

The point to bear in mind, however, in each of these conditions is that under average *present day* conditions we will find, more often than not, that the lens *correction itself will eliminate the photophobia.*

We will consider the patient whose working surroundings are not normal regarding light intensity and/or quality. Under this heading would fall all those who have to drive a great deal, particularly on white roads; etchers, watchmakers, engravers, and workers using intense illumination for close work. If such a patient is found to be photophobic after correction with lenses, we should do something about it; indeed, should consider it before the correction is made. Bearing in mind that this patient may have a high, normal, or low systolic blood pressure, we now have some idea as to how to proceed.

A study of the various spectrum transmission charts will be of value in further study. It will be noticed that various sorts of absorption lenses do several things to the visible and invisible rays. Blue and azure tinted lenses tend to eliminate the long-wave-lengths (red and infra-red), and hence are of value where great heat is associated with glare. It would also seem that their use would be indicated in certain selected cases of senile cataract as we wish in these cases to eliminate the metabolic heat action of the longer infra-red rays as they seem, according to certain investigators, to hasten the formation of the opacity.

Euphos (green), green-yellow (fieuzal), calobar (blue-green) and amber glass all cut down on both ends of the spectrum (infra-red and ultra-violet), as well as cutting into the yellow in several ways. Such tints would be suited to cases in which we required both actinic and heat-reducing qualities.

Certain pink and amethyst-tinted lenses such as Softlite have the valuable quality of reducing the intensity of visible rays without disturbing their relative values, which is of importance in many cases. (Gem experts, artists, etc.) The deeper shades of these tints are probably more valuable than the lighter ones for actual photophobia, and serve admirably for a second pair of glasses to be used on special occasions such as the occasional long drive, the visit to the beach, etc., where no abnormal condition exists in the eyes that needs a special absorption lens for continual wear.

Many patients use the lighter shades of this (pink) tint continually for cosmetic reasons, as it shows little contrast to the normal brunette skin. No harm will be done in such a case; even if his patient have a high systolic blood pressure, the fact being that these lenses transmit the invisible ultra-violet radiations just about as does ordinary crown glass and that in the lighter shades they merely absorb a relatively small even portion of the entire visible spectrum which passes through them. This portion, in the lighter shades of Softlite absorption glass, being so

small as to be of little or no importance in cases having a high systolic pressure.

High systolic blood pressure associated with cataract (a condition frequently met with) *requires* a blue or azure-tinted lens, as this lens will absorb heat rays (indicated absorption for cataract) and allow ultra-violet to be transmitted (indicated transmission in high blood pressure).

Both arctic and tropical explorers find that fieuzal, euphos, calobar and novial are great aids, the latter being, for some reason, very popular with arctic explorers. It may be noted that many people in temperate zones are made quite uncomfortable with novial lenses (frequently mistaken for amber), but will wear the fieuzal with comfort; the novial, however, seems to be an excellent preventive for snow-blindness.

Workers using acetylene and electric torches should have special goggles for this purpose, and no attempt made to incorporate a correction in them. Several tints are available, but all should absorb both infra-red and ultra-violet as well as cut the total transmission considerably. A very dark shade of Calobar, 2.2 mm. in thickness should answer this purpose.

The author has had only about three albinos requiring visual attention, all of them being photophobic and all having high refractive errors. In none of these cases was the photophobia satisfactorily relieved, the best results being obtained on one case with Crookes B.

CONCLUSION: (1) Be sure that your patient's photophobia is not due to a refractive error before considering any tinted lens.

(2) Bear in mind that high systolic blood pressure cases cannot wear an actinic lens, while low systolic pressure cases require such a glass.

(3) Give special consideration to cataract cases; if such a case is associated with high blood pressure, avoid an actinic lens, using blue or azure tinted lenses. If the blood pressure is below the average, euphos A, calobar or fieuzal, is indicated; the latter two only where the blood pressure is normal or below normal, as they all cut into or eliminate the shorter wave lengths of the spectrum, a contra-indicated absorption in high blood pressure.

(4) Pink, amethyst and Softlite shades are of particular value where uniform reduction of the visible spectrum is the desideratum, the lighter shades being used where slight reduction of high intensity is desired and for cosmetic reasons, the darker shades for exceptional glare and for a second pair to be use occasionally.

(5) Finally, do not prescribe any tint without a definite reason, and particularly avoid actinic lenses (as well as all lenses of unknown absorbtion), except in cases that you know the results you wish to obtain are to be had with the quality glass being considered.

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A THEORY OF COLOR VISION

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In response to a request from the President of your Science Class, I have the pleasure of meeting with you this afternoon and talking to you about Color Vision.

It is obvious that all speculation and assumption concerning the Function of the Eye must be preceded by, and founded upon, a thorough knowledge of the minute Structure of the Eye.

And so before discussing this phenomenon, I shall attempt to give you a better understanding of that part of the Anatomy of the Eye which concerns Color Vision, than you have probably acquired so far in your school work. In order to do this it may be necessary to dwell upon certain facts which apply to the structure and function of the Eye, which at first do not seem to be concerned with our seeing of colors.

(Here we present a section of the Eye showing the several coats, Drawing I.)

The eyeball, as you all know, is composed of an outer covering filled with liquid of greater or less density in its various parts. This outer covering is made up of three distinct membranes, the outer one a tough inelastic tissue much like the gristle found in beefsteak except that it is whiter: the middle one made up largely of blood vessels: the inner one composed mostly of nerve tissue.

A microscopic investigation presents the following picture of these coats in the order named.

First: The outer coat shows many layers of fibres running in different directions, and so tightly woven, and so inelastic, that it holds the Eye to a constant size and with very little variation in shape. When

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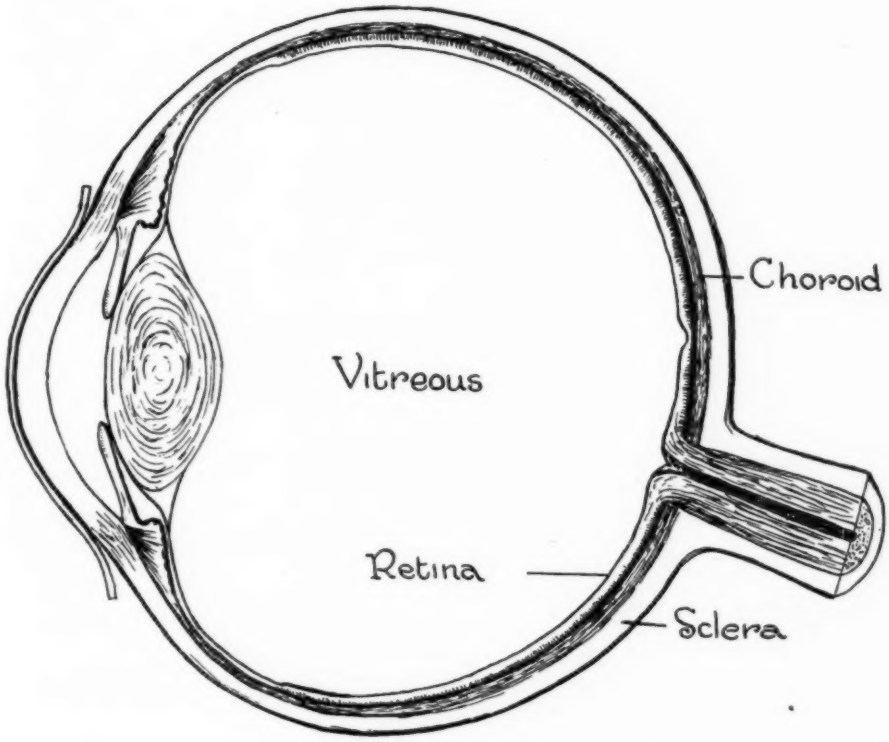
*This paper comprises a brief talk on the EYE and its FUNCTIONS, given in response to requests by the Science Classes of various High Schools. The author has endeavored to tell his story without being so technical as to place it beyond the comprehension of his audience, while avoiding that childish simplicity, which might appear to minimize the intelligence and understanding of the High School student, who has already become familiar with much of the gross Anatomy and Physiology of the Eye, and with some of its technology. Submitted for publication Jan. 20, 1934.



Dr Harry Lee Fording. Drawing I. The Eye showing various Coats.

we consider that the internal pressure of the inclosed liquids which are constantly passing in and out may be even 30 times that of the pressure of the air upon the outside, we can readily see how strong and inelastic must be this fibrous coat.

Then, too, it is not easily punctured, and so insures the inner coats against injury by the penetration of foreign substances.

Then between its fibres (excepting a small section in front) is found a cohesive glue-like substance, and between its inmost layers a dark brown pigment. These substances render this coat opaque and thus give protection from oblique and excessive light.

And because its chief function is to Preserve and Protect, it is called the Protective coat.

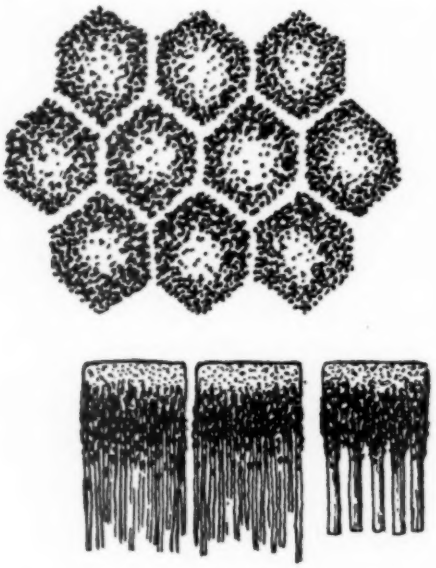
Second: Then just inside this protective coat is a thinner membrane made up of a network of connective tissue fibers holding within its meshes many Arteries, Veins, and Nerves, which run forward from the back of the ball to the little opening in front we call the Pupil, and constantly sending off branches to the inmost coat. Because this coat

is made up largely of blood-vessels, and because these vessels carry nutrition to all the tissues of the Eye, it is called the Vascular or Nutrient coat.

Third: Just inside the Vascular coat, and firmly attached to it is the important coat of the Eye called the Retina. This is the Sensitive coat.

If Nature's purpose in constructing the Eye is to give us Vision, then the Eye, like the Camera to which it is so often likened, must have a sensitive film upon which the pictures may be produced. And so in this innermost coat of the ball, Nature has formed a most marvelous film. If we think of the Eye as the organ of Vision, then we must think of this Sensitive coat as the coat of prime importance, the one holding within itself the whole function of the Eye, while the outer coats are only subservient to it: the one affording Nutrition, the other Protection.

(Here we present a schematic illustration of the pigmented cells of the Retina, Drawing II.)



Dr Harry Lee Fording.
Drawing II.
Schematic illustration
of the Pigmented cells
of the Retina.

A very schematic drawing of the Retina presents a layer of hexagonal columnar cells, laid like pavement blocks upon a very smooth and inelastic fibrous layer, which makes a very firm foundation for these

columnar cells. This layer of cells with its basement membrane is considered by some anatomists as a part of the Vascular layer, by others as a part of the Sensitive Layer. A more exact description of it must consider it to be structurally a part of the Vascular coat, but functionally a part of the Retina.

These cells develop within their protoplasm an unusual number of pigment granules, for which reason they are often designated as the Pigment layer of the Retina. A part of these pigments granules are of a dark brown color, and are good conductors of electricity, and consequently of light; a part are of a reddish-yellow color and are poor conductors. (The importance of this conductive power we shall refer to later on.)

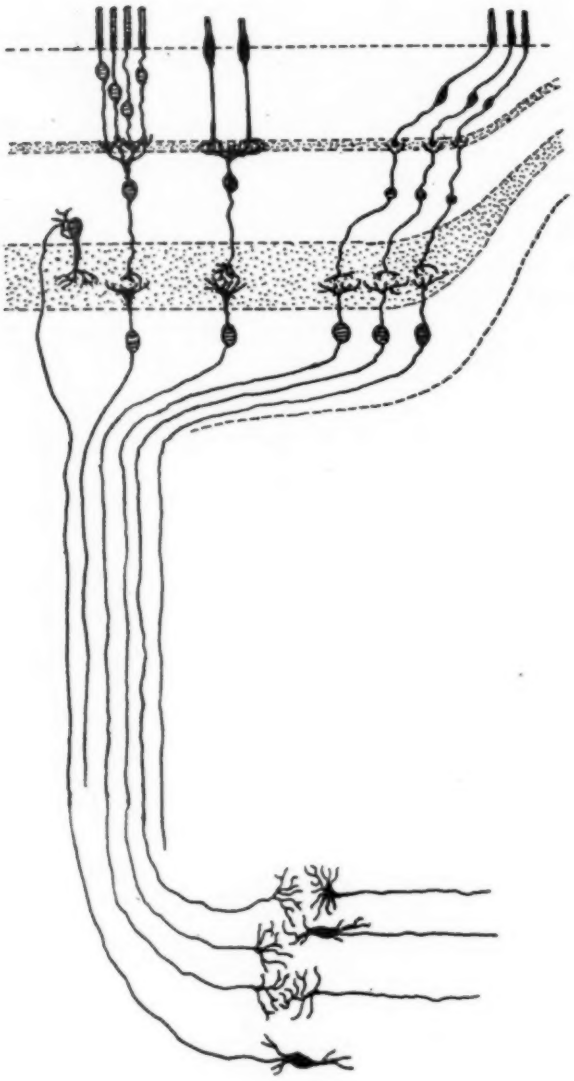
Then from the inner surfaces of these cells are developed many minute hair-like processes called Cilia, which become extended under the stimulus of light to lie among the nerve elements of the adjacent layer of the Retina. These hair-like, or filiform, processes present at intervals along their course bead-like enlargements. These are thought to be pigmented drops of the protoplasm of the cell passing along through the central canal of the Cilia. So that as the Cilia become extended these drops of protoplasm appear to travel toward their distal ends. Or we may call them lymph globules, probably containing the pigment and mineral elements which give color to these cells, and also suggest a very important function to be emphasized later.

If we continue our microscopic study of the Retina, we find that it is made up largely of Nerve elements, which are called Neurons. Here we find that the typical Neuron comprises a cell body sending out in opposite directions long processes or fibres as shown in our drawing of the Retina. (See Drawing III.)

At the outer ends of these nerve fibres of the first Neuron in the chain we discern two kinds of endings, (here is shown a schematic drawing of a Rod and a Cone, both highly magnified; Drawing IV) one being formed of a solid element shaped like a rod or pencil; the other more like an egg with a small cone projecting from its smaller end. The first we call the Rods of the Retina, the second the Cones. These Rods and Cones are called the receiving elements of the Visual apparatus.

We must now dwell a moment on the structure of these receiving elements, for their structure must prove a determining factor in our conclusions as to just what takes place when light is transmuted into electric (or nerve) currents.

Looking first at the Rods we see them made up of two segments, an outer cylindrical one nearest the layer of pigmented cells and transversely striated. By means of certain alkaline solutions it is learned that these Rod-segments are built up of two kinds of tissue. One is a nerve tissue much like the white myelin sheath of the typical nerve fibre, a poor conductor of electricity (or as you say in Physics, a good dielectric). The other is a fibrous tissue, much like the dermal layer of the skin: this covers the rods and dips in and divides the myelin substance into



Dr Harry Lee Fording
Drawing III.

about 60 thin plates or discs, which according to Max Schultze (an eminent German Physiologist) are only about .0006 mm. in thickness. This covering membrane with its transverse partitions is a good conductor of electricity and hence of light. This structure gives to this

cylindrical segment of the Rod, under high magnification, the appearance of a Condenser, comprising a series of so-called Franklin plates.

In the inner segment of the Rod which is slightly elliptical in shape, are seen many longitudinal striations which quickly fade away under the microscope and become lost among the numerous and ever-present granules filling the plasma of this segment.

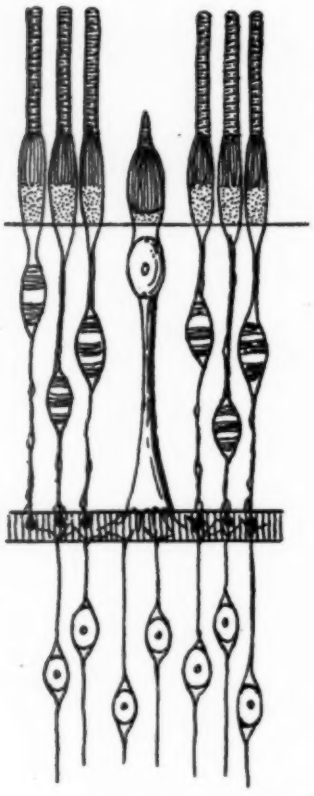
The cell bodies of these first neurons, of which the Rods are the modified nerve endings, lie within the next layer of the Retina, and being much more numerous than those of the Cones, make up the greater portion of the so-called outer nuclear layer. These cell bodies, like the outer Rod segments, show transverse striations under certain stains, but these are limited always to three or five bands. These cell bodies are not equally distant from the Rod-ellipsoid, but appear at many levels between the Rods and the bead-like endings of their Axons.

Let us now observe the Cones. In structure they are so much like the Rods that we are inclined to think that they may almost subserve the same purpose. The outer segment is shorter, with fewer plates, and is conical instead of cylindrical. The Cone-ellipsoid is much thicker than the corresponding segment of the Rod, and the striated portion of the segment is more pronounced, and the granular less so. Then the cell bodies lie uniformly close to the Cone-ellipsoid and do not show the transverse striations. And their Axons end in arborizations or minute processes unlike the bulbar endings of the Rods. How these variations in structure may alter the function of the Rods and Cones still remains an unsolved but interesting problem.

In the other layers of the Retina made up of the 2nd and 3rd neurons of each visual chain the essential structural variations to be noted lie in the varying levels of the cell bodies and in the diverse structure of the synapses. (See Drawing IV.)

The variations in structure of these neurons which begin in the Rods and Cones and make up the distinct nerve tracts of the Retina, and the varying levels of their cell-bodies and their synapses, suggest to the rational mind a definitely planned function for each individual chain, with a common purpose for all: a "harmony not yet understood." Like Pope's garden, 'Where flowers in endless variety we see; and where though all may differ, all agree," so the endless variations of structure and position of the cells and synapses of the Retina, affords an ample field for speculation and assumption. And while no definite theory has been generally accepted, no more rational hypothesis has been suggested than that the common purpose of it all is to transmit nurve currents varying either in their rates of transmission, or in their wave lengths, or both; thus causing the nerve impulses to be received at different times and with varying vibrations by the receiving cells of the visual cortex.

Returning again to the Rods and Cones we find them surrounded by a liquid which we will call lymph. Into this lymph is thrown a pig-



Dr Harry Lee Fording
Drawing IV.

ment called rhodopsin, or visual purple, which many of the earlier histologists thought to be secreted by the Rods. But as the Rods have the typical structure of an electric condenser (as we have seen in our drawing) and not the structure and form of a secreting cell, it seems more reasonable to assume that this visual purple is secreted by the layer of columnar mucous cells already described.

It has already been told how these same cells secrete a dark brown, and a reddish-yellow pigment. It has been suggested by some physiologists that these mucous pigmented cells secrete also several of the mineral elements as components of this pigment, among which is the mineral Selenium.

This mineral Selenium was accidentally discovered by a Swedish scientist named Berzelius about 1817, as a by-product in the making of sulphuric acid. It is seldom heard of outside the precincts of the labor-

atory, and its importance is little known today outside the domain of Physical Science. This mineral is the only one known to Science which has the power of transmuting light waves into electric waves, or into Nerve Impulses, which are now thought to be the same as electric currents.

Selenium has been obtained in two forms, one of a reddish-yellow color which conducts little heat, and no electricity; another of a reddish-black or dark purple color, which is a good conductor of heat, and a still better conductor of electricity.

Its conductive power is very much decreased when placed in a light medium. For this reason it has been constantly used in laboratory experiments for more than a century in perfecting such instruments as the photometer, photophone, electroscope, telectroscope, and telephone. One can not read the history of the telephone without appreciating the importance of Selenium in its development. The first suggestion given to the scientific world of the possibilities of Television was by a Polish scientist who more than thirty years ago was experimenting with Selenium.

This Selenium may be projected in the lymph globules through the extended cilia, as heretofore suggested, or it may be thrown off in the manner of the typical mucous secretion to be held in solution in the adjacent lymph. Whichever hypothesis is correct, the presence of Selenium granules projected among the Rods and Cones, and influenced as they are in their power of conduction by the varying intensities of Light to which they may be subjected, may offer a plausible solution of the accompanying phenomenon, the transmutation of Light Waves into Electric or Nerve Currents, of varying wave lengths.

Now when the Light Waves have been transformed into Electric or Nerve waves they must be transmitted to the Visual Areas of the brain upon which are formed the mental pictures of all things seen.

The Rods and Cones are no doubt the receiving elements of these Nerve Currents. Their immersion in the Retinal lymph and their structure as heretofore described, admit of no other reasonable conclusion.

The apposition of the countless granules of Selenium held in solution in the surrounding lymph or projected in the nodules of the Cilia, together with the segmented structure of the Rods and Cones, with their power of contraction and dilatation (like the sarcostyles of a striated muscle), form a marvelous apparatus for the transmutation and transmission of Light.

A consideration of the efficiency of this apparatus must not neglect that form of Selenium which does not conduct electricity. For as a non-conductor it may perform a negative function of no less importance in the economy of the Eye. Is it unreasonable to suggest that these reddish-yellow granules of Selenium, through an increased secretion, may neutralize the conductivity of the darker granules whenever Nature finds it necessary to give protection from the injurious effects of a too intense

light? May it not then act as a necessary neutralizer or stabilizer of the nerve current?

Then, too, where the most highly developed and most sensitive cones of the Retina are found, in a very small area at the posterior pole, we observe a predominance of these reddish-yellow granules. And why? Do not these hypersensitive cones especially call for the protective and stabilizing influence of these non-conducting Selenium granules?

This small area of most acute vision has often been designated as the "yellow spot" of the Retina. No more plausible explanation for this has ever been given than the one here suggested that it may be due to an aggregation of these reddish-yellow granules of Selenium.

Now let us return to the receiving elements: from these rods and cones the nerve impulses, or electric waves, pass along the nerve fibres of three distinct Neurons having their cell bodies in the Retina. (See Drawing III.) The third Neuron sends its distal fibres out of the eyeball and back along the base of the brain till it reaches a large mass of gray matter, known as the Thalamus, in which it forms a junction, or Synapse, with another Neuron which passes to the posterior lobe of the brain. These neurons form the so-called Optic Nerves, Optic Tracts and Optic Radiations. And all the rods and cones of the Retina, which number at least three million cones and thirty million rods, are connected (either singly or in groups) by these Neurons with a half million or more cells which compose a distinct area in the back of the brain known as the Cuneate Area or the "Seat of Vision."

The question then presents itself, do these Rods and Cones and the nerve fibres which form the Optic Nerves and Tracts and Radiations transmit alike all Light vibrations from the shortest violet to the longest red, or are they attuned to various wave-lengths, each chain of neurons with its specialized ending in the Retina receiving and transmitting only vibrations between certain fixed limits? Almost every consideration persuades us that the latter assumption is the most plausible solution of the problem. We know that the sensations of the Retina last much longer than the stimuli: the sensation lasting about one-eighth of a second, while the stimulus may last only one-eight hundredth. Hence a "piling up" of the effects of various stimuli may produce many differing sensations.

Then, too, the structure of the Retina, to which your attention has been already directed, indicates that the nerve currents are either accelerated or slowed down by the synapses, and at varying times in their transmission, due to the varying levels at which these synapses are placed.

It is a well established fact also that the Rods and Cones move toward and away from the pigment layer of secreting cells, thus facilitating or delaying the nerve current, and acting as a common Rheostat. The same may occur at the synapses of the several neurons which make up the visual chain.

So that if the Rods and Cones be attuned to the reception of the three primary colors: red, green, and blue, or to the seven colors of the visible spectrum, the "piling up" of the stimuli may produce many varied sensations, many colors upon our mental screen.

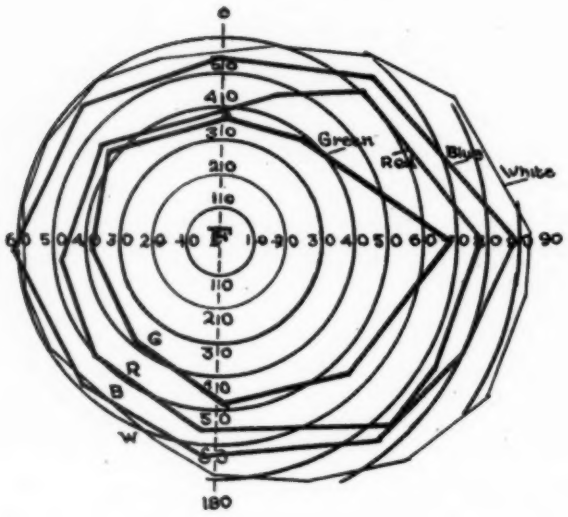
We must now say a few words concerning the development of the Eye, not in the individual, but in the human race; in other words, the evolution of the eye as it is generally agreed upon by those men whom we call Anthropologists. The generally accepted theory of this evolutionary process is briefly this: the eye first distinguished only Light and Darkness, the Retina comprising rods only. In time these rods in the small area called the Fovea, which is the area most used, developed into Cones and in the process of development gave to the eye the power to distinguish the Form of objects. And further development of these cones in time brought about the ability to distinguish Colors, this being due probably to their ability to receive different length vibrations of light, just as the radio today may be tuned in to receive different vibrations of electric waves. And so in the development of the eye it passed through the three stages which we may call Light vision, Form vision, and Color vision.

No thesis on Color Vision should omit a few facts concerning the so-called "Color-fields" of the Retina.

Now in the Retina, the cones and rods are not evenly distributed. At the posterior pole of the eye, just above where the Optic Axis passes through the Retina, is a small area (heretofore spoken of as the area of acute vision), less than half a millimeter in diameter, which contains about thirteen thousand Cones and no Rods. This minute area, as you know, is called the Fovea. Outside of this foveal area the cones rapidly decrease in number and the rods correspondingly increase. This posterior central area, made up entirely of Cones, and probably the most highly developed Cones, is capable of seeing all the colors of the visible spectrum. Outside of this foveal region as the cones decrease in number and development, the sensations of color become altered so that when we reach a point, say forty degrees from the Fovea, we cannot distinguish all colors. (Here we show a drawing (No. V.) of the color fields of the Retina in green, red, blue, yellow, and white.) As seen in the drawing, the ability to distinguish green disappears first, then red, then blue, then yellow, and beyond this only white is distinct. These so-called "color-fields" of the Retina become altered in size and shape under the influence of the varying toxic, septic, or infectious conditions of the blood, so that many systemic diseases, or conditions, are diagnosed quite accurately from these color-fields. This opportunity for Diagnosis affords a very extensive and important field for both the Optometrist and the Oculist.

During the past century, several theories of color vision have won many adherents, but none has gained general acceptance.

The first theory of Color Vision which attempted to explain the relations of Retinal Stimuli to the sensations of Color was suggested by



Dr Harry Lee Fording
Drawing V.

that eminent physicist Thomas Young (1801), and was later elaborated upon and made more acceptable by von Helmholtz.

This theory now known as the Young-Helmholtz theory, advocated *three* distinct sets of fibres in the Retina and Optic paths; those that transmit light vibrations of the least, the intermediate, and the greatest rapidity; or in other words, the short blue waves, the intermediate green waves, and the long red waves. These three sets of fibres, with their specialized nerve endings, were assumed to transmit all the wave lengths, and hence all the stimuli of the solar spectrum. By the simultaneous stimulation of the three types of nerves, or nerve receptors, in a certain proportion the composite sensation would be white; in all other proportions the sensation would be one of color; this color being dependent on which of the fundamental colors, red, green, or blue, predominated. Thus the added effects of varying wave-lengths could produce all the recognizable sensations of Color and Hue.

One of the postulates of Young's theory was that the Retinal lymph held in solution "some substances unknown to Chemistry," two of which he called "visual yellow" and "visual purple," which in some way "facilitated the transformation and transmission of Light." This was before the discovery of Selenium. Note how the acceptance today of Selenium as a necessary factor in the transmutation of Light into the Nerve Current explains the postulate of Young, and fulfills his implied prophecy.

The only theory that has rivaled the Young-Helmholtz in popularity is that of Ewald Hering, an eminent German Psychologist.

The Hering theory, instead of being based on three fundamental colors, postulated the existence of three sets of complementary colors giving *six* fundamental sensations, namely, black and white, red and green, and yellow and blue. All hues are then derived from the various combinations of these sensations.

Other theories have been suggested by Christine Ladd-Franklin, by Donders, by McDougall, by Wundt, by Edridge-Green, and by others, but they all seem to be modifications and elaborations of the Young-Helmholtz, or the Hering theories.

A protracted study of the minute structure of the Retina and the Visual Tracts, and of these various theories of Color Vision, may easily persuade us that if any theory ever becomes generally accepted, it will be based upon these three hypotheses:

(1st) that the mineral Selenium (or an association of mineral elements in the pigment of the Retina having the same peculiar property) transmutes the Light waves into Electric Currents of like wave lengths, these constituting the so-called Nerve Impulses:

(2nd) that these Nerve Impulses are received by the Rods and Cones which act as Condensers: that their movement toward and away from the pigment layer together with the associated movements of the Pigmented Cilia, and the possible movements of the Synaptic Endings of the several neurons of the Retina, constitute a Rheostat, which slows down the Nerve Currents, and alters their individual and combined effects:

(3rd) that these individual and combined effects which we call Sensations give us that Special Sense to which we have given the name Color Vision.

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NOTE I. There are other quite well established facts and plausible theories concerning the structure and function of the Eye, which relate to Color Vision, and which must find a place in any complete treatise on Color Vision.

NOTE II. The writer is indebted to Mr. Eugene Miller, now a Senior in the North Pacific College of Optometry, for the drawings herein shown.

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LIGHTING AND VISION

The problems of lighting and those of ocular comfort are so closely related that it is practically impossible to study one without considering the other. This being true it is therefore evident that we as optometrists, interested as we are in developing comfortable vision for our patients, must, to be successful in this, give more thought to this important requisite of seeing, i.e., lighting.

Not only must we study this matter of lighting from the standpoint of having sufficient illumination for the task at hand, but also from other phases of this important attribute to comfortable vision. For instance, the requirements which must be met in the choice of reflecting equipment and in the design of a satisfactory lighting installation for industrial plants according to Cushing[1] are:

1. A steady light of sufficient intensity on all working surfaces whether in horizontal, vertical, or oblique planes;
2. A comparable intensity of light on adjacent areas and on the walls;
3. Light of a color and spectral character suited to the purpose for which it is employed;

[1]Standard Lighting. H. C. Cushing, Jr., page 63, 1922.

4. Freedom from glare and from glaring reflections;
5. Light so directed and diffused as to avoid objectionable shadows or contrasts of intensity;
6. A system which is simple, reliable, easy of maintenance, and reasonable in initial and operating cost.

In addition to these necessary lighting requirements, good comfortable vision depends also on several other important anatomical and physiological factors. These factors are:

1. The correction of all existing refractive errors:
2. The complete freedom from imballances of the accommodative and convergence functions;
3. The absence of all ocular pathology.

However, assuming that these last three factors have been carefully taken care of by us as optometrists, our work as ocular specialists has not been finished until we have made sure that the patient's general lighting conditions at his or her working place or in his or her home is of such high character as to permit them to accomplish their usual tasks without becoming subject to the type of ocular fatigue engendered by either glare or that brought on by under-illumination. It is well to remember at this point that an object is seen by the light which it reflects rather than by the light falling upon it; hence, housewives working on dark materials or textile mill workers engaged in manufacturing dark colored fabrics require higher intensities of illumination for this work than when working on light colored fabrics. Manufacturing processes involving fine machine work or fine assembling require more light than industries where a comparatively low degree of accuracy suffices. The greater alertness and better morale of the workmen in the brightly lighted surroundings are at once apparent in the greater production of the plant, and according to lighting specialists there is a growing conviction that no one should be called upon to work continuously at any occupation under an intensity of less than one foot-candle regardless of how rough the operation may be. It is interesting also to note that in plants where the most study has been devoted to lighting and the proper intensities have been adopted, that production costs have declined. Durgin[2] made tests in four Chicago plants where accurate cost and production records could be kept and showed that by increasing the illumination up to 10 to 12 foot candles, the production increased from 10 to 35 per cent at a cost for lighting of only 1 to 5.5 per cent of the pay roll, and that the workers not only did more work but did it better and with less ocular fatigue.

It is an unfortunate fact that many employers consider this matter of light, in a sort of a perfunctory way; to them any sort of an illuminating device will suffice and the entire matter is treated with an alarming amount of indifference. Those of us in the optometric profession must

[2]W. A. Durgin. Electrical World. March, 1919.

assume the duty of educating the employer, the great mass of workers, housewives and even the educators themselves to the need of a more careful study of individual lighting problems and also to awaken in the minds of all persons the desire to improve their lighting conditions to a point where it will at least eliminate all danger of ocular fatigue.

To eliminate the danger of ocular fatigue due to improper illumination, many engineers and illuminating specialists have worked for years. Men such as M. Luckiesh and his co-worker, Frank K. Moss, S. E. Doane, G. H. Stickney, D. W. Atwater, A. B. Oday, W. Harrison, A. L. Powell, S. G. Hibben, H. A. Smith, R. E. Harrington, A. S. Turner, C. A. Atherton, E. A. Anderson, J. H. Kurlander, G. A. Clewell, H. H. Magdsick, and J. R. Colville and many others have done much fine work in the plants and factories themselves; these men have set up and followed through elaborate experiments and it is largely because of this work that we are now able to advise our patients as to the proper minimum amount of illumination that it is safe to have at any particular task.

The following table compiled by Cushing can be used as a guide to show the lowest possible amount of illumination which will enable the otherwise normal worker to "carry-on" his or her work with safety, accuracy and an absence of ocular fatigue. In this table illumination requirements are specified in foot-candles. The term "foot-candle" may be explained by saying that it represents the illumination on a surface one foot distant from a standard candle; two foot-candles would represent the illumination supplied by two candles at the same distance, etc. In this table it is assumed that in each case the surface is perpendicular to the direction of the rays of light falling upon it.

Minimum Illumination Requirements Table

	Minimum Foot-Candles on the Space or at the Work
(a) Roadways; yard thoroughfares	0.02
(b) Storage spaces; aisles and passageways in workrooms excepting exits and passages thereto	0.25
(c) Where discrimination of detail is not essential. Spaces, such as: Hallways, stairways; exits, and passages leading thereto; toilet rooms; elevator cars and landings. Work, such as: Handling material of coarse nature; grinding clay products; rough sorting; coal and ash handling; foundry charging	0.5
(d) Where slight discrimination of detail is essential. Spaces, such as: Stairways, passageways and other locations where there are exposed moving machines, hot pipes, or live electrical parts.	

Work, such as: Rough machining, rough assembling; rough bench work; rough forging; grain milling ..... 1.

(e) Where moderate discrimination of detail is essential. Work, such as: Machining; assembly work; bench work; fine core making in foundries; cigarette rolling ..... 2.

(f) Where close discrimination of detail is essential. Work, such as: Fine lathe work; pattern making; tool making; weaving light colored silk or woolen textiles; office work; accounting; typing ..... 3.

(g) Where discrimination of minute detail is essential. Work, such as: Watchmaking; engraving; drafting; sewing dark colored material; weaving dark textiles, etc. ..... 5.

The illumination values given in this table are minimum requirements dictated from the viewpoint of safety. Persons of advanced years and those with visual defects require more light than those having perfect vision. The foot-candles in good lighting practice are as a rule several times those specified as minimum requirements.

Keeping these facts regarding the need for proper lighting in mind, it is well to turn for a moment to the groupings or classifications of various occupations according to the frequency of eyestrain as made by Dr. George M. Gould[3]. In an exhaustive study of this matter he found that from 60 to 80 per cent of the persons in the following occupations subject to ocular disorders:

Housewives	Watchmakers	Clergymen
Bakers	Dentists	Clerks
Garment makers	Engravers	Journalists
Chemists	Glass blowers	Teachers
Telegraphers	Proofreaders	Stenographers
Tool makers	Hatmakers	Physicians
Lawyers	College students	Bookkeepers
Wood carvers	Leather goods workers	Telephone operators
Authors	Textile workers	Cigarmakers
Barbers	Musicians	Tailors
Draftsmen	Miners	Diamond cutters
	Power machine operators	

As the majority of these occupations fall into the (f) group or the (g) group of the foregoing table it is obvious that a definite need exists, not only for proper optometric care but also for an intelligent and aggressive optometric policy as regards to illumination problems, particularly with reference to its beneficial effect upon the eyes of the workers of this nation. Not only does this apply with force from the angle of conserving visual nerve energy but it applies with equal force in the field of safety and accident prevention.

Mr. R. E. Simpson[4] is authority for the statement that during the year 1919 there were more than 2,000,000 industrial accidents caus-

[3]Gould. Seeing by Luckiesh and Moss, page 163, 1933.
[4]Simpson, R. E. Travelers Standard. 1919.

ing loss of time; of this number, 25,000 were fatal. The following extract from an article by Simpson gives some interesting data on the relation between lighting and safety:

> "There is some foundation for assuming that 18 per cent of our industrial accidents are due to the defects in lighting installations. On that basis the services of 108,000 men for one year are lost annually because the illumination provided is not adequate for the safety of the workman. That this condition could exist year after year is all the more reprehensible, because of the fact that the remedy is so easily applied and has beneficial results in many ways other than the safety involved. Accidents caused by carelessness, inattention or ignorance can be eliminated only by a long continued, painstaking, educational campaign, often involving a change in long established habits. Elimination of accidents, due to improper lighting is simply a matter of purchasing the proper equipment, and installing it under competent direction. In fact, it seems proper to include illumination in the list of mechanical safeguards, for the reason that the lamps and reflectors provide a guard; illumination points out the hazards just as effectively as a railing points out the danger of, and provides protection against, the hazard of a revolving flywheel."

It is therefore evident that the need exists for proper and adequate illumination. Illumination that will make for better working conditions; more efficient and more accurate work; increase the general all-around efficiency of the entire force; reduce costs; cut down the number of accidents and particularly reduce the unnecessary ocular strain now experienced by many workers due to carelessly placed lights or to a general lack of illumination.

This is an important matter. It is too large a problem to be left entirely to the small hand-full of Illuminating Engineers found in the various industrial centers. It is a problem that each and every optometrist can assist in solving by intelligently discussing the subject with his patients. As a professional man it is entirely within his jurisdiction and as an optometrist it is indeed fitting that he include this sphere of activity among those of close interest to him. His remarks on this subject will be listened to with attention, for as a professional man he has nothing to sell in the way of lighting fixtures. His interest is purely an academic-professional interest in his patients' well-being. As optometrists, our interest is to conserve vision, and if this can be done by improving general lighting conditions it is up to all of us to assist in every way possible.

In a book called "Seeing,"[5] published during the close of 1931, the authors, Luckiesh and Moss, have this to say on the subject:—

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[5]Seeing. Luckiesh and Moss. Published by the Williams & Wilkins Co., Baltimore, Md., 300 pages. Ill. $5.00.

"Seeing is a partnership of lighting and vision. Optometrist, oculist and ophthalmologist focus attention on the eyes. Illumination engineers focus it on the supply of adequate light free from glare. The two sciences have rarely met in the laboratory. The two arts are strangers in the world of practice. As a consequence, seeing is neglected." This is a book written by an illuminating engineer for the optometrist. It tells the entire story in an easily understandable manner. Every student of optometry in our colleges should read and study this work. Every practitioner in the field should acquire this book and become familiar with its contents. as it deals with a necessary form of preventive optometry and a form of hygienic activity long neglected by members of our profession.

C. C. K.

* * * * *

BOOK NOTICE

THE HEROIC AGE OF SCIENCE. William Arthur Heidel, published by the William Wilkins Co., Baltimore Md. 203 pages, cloth binding, 1933. $2.50.

Heidel, in preparing this book, "The Heroic Age of Science," rendered a distinct service to science and scientists. He traced carefully the original connections of Greek science with other pseudo sciences like religion, magic, etc., and the attempt the Greeks made to emancipate themselves from earlier beliefs. He points out that at the beginning of the scientific development there were no special catagories nor special methods and technics of the type we have today. It was only the native intelligence, exercised in practical affairs which aroused the curiosity of the thinker. The Greeks had to depend upon their native resources to lay the foundation for the mammoth structure of science. They did not have any laboratory facilities to test their hypothesis or theories, and had, therefore, to use speculation instead of observation. In spite of this handicap, many of theories formulated by the early Greek thinkers prove to hold true now when put to the laboratory test.

Their work was not limited to any special field. They contributed to Mathematics, Astronomy, Medicine and even Modern Psychology can be traced back to Socrates, Plato and Aristotle and others. This book has a definite cultural value and will unquestionably be welcomed into the libraries of most cultural people.

J. I. K.

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